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SOME ASPECTS OF ACCEPTANCE SAMPLING

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Acceptance sampling, coupled with inspection, is used to distinguish acceptable from non-acceptable lots or shipments. It may be applied to materials coming into a plant, to products passing from one operation to the next and to final inspection. Its use and the degree of its use depend upon its practicality. The cost of using acceptance sampling must be less than the reduction in tangible and intangible expenses of spoiled product, production downtime and adjustment of complaints realized or anticipated from its application. Acceptance sampling within the operation may not be justified if established process controls are effective or if in-process inspections of other types are equally effective and cheaper.

The accumulation of data which allows the calculation of the process average, or the average number of defects, is a valuable part of the acceptance sampling technique. Such data may be used for rating vendors, determining the quality of ware leaving the plant or for comparing the quality of work performed in the operation by various groups and their equipment. There are other advantages in the use of acceptance sampling in addition to the necessary cost reductions which justify its adoption. Definite rules are laid down for sampling, acceptance and non-acceptance. The long-range operation of these rules can be predicted. Materials which have successfully passed the acceptance sampling procedure may be largely eliminated from consideration as the causes of production difficulties, thus allowing concentration on other aspects of the operation. This assumes, of course, that the sampling inspection procedure is adequate in concept and execution. Finally, experience seems to indicate that quality generally improves after the institution of acceptance sampling procedures.

Acceptance sampling programs may be based on inspection by attributes or inspection by variables. In attribute inspection, the individual pieces of the sample are classified as being defective or not defective. In inspection by variables, each piece is examined, and the degree of variability and the average of the individual observations for the sample are used to predict the acceptability of the lot. This discussion will be confined to acceptance sampling based on inspection by attributes. This arbitrary limitation is not intended to reflect in any way upon the relative merits of the two approaches. It is based on the writer's experience with respect to the relative application in the field of his interest. This experience may not be universal and it may change in the future.

There are many sources of confusion as the novice looks on acceptance sampling for the first time. There is a vocabulary to be learned. Usually there must be an adjustment of thinking in connection with samples and the meaning of samples. There is the matter of choice of proper sampling plans from the many available. Which is the one for brick? For dishes? For bottles? There comes a realization that the sampling plans and tables can be used for almost any product for which some degree of quality assurance through sampling inspection is worthwhile. It becomes clear that the sampling plan is as much a part of the specification as statements of dimensions, weights, strength and other qualities, with their respective tolerances.

A sampling plan is a statement of the number of pieces (n) to be taken as a sample from a lot or shipment and the maximum number of defects or defective pieces (c) allowed in that sample if the lot or shipment is to be accepted. A plan which is denoted: $n = 100$, $c = 1$, means "take a (random) sample of 100 pieces and accept the lot if 1 or fewer defects (or defective pieces) are found." This statement may imply that all lots having 1% ($\frac{1}{100} \times 100$) or less defects will be accepted, but this is not true. A sampling plan which distinguishes between lots containing 1% defective items and lots having more than 1% defective items, for instance, is certainly desirable, but it remains an ideal which is attained only by an accurate 100% inspection. If there is more than 1 defective piece in the lot, regardless of how large the lot may be, there remains a chance that the sample of 100 will contain more than 1 defective piece. If there are only 99 good pieces in the lot, there is some chance that it will be accepted by the sampling plan described here which permits

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acceptance of samples containing 1 bad and 99 good pieces.

If there is a difficulty in the practical interpretation of sampling plans, this difficulty possibly arises from a misunderstanding of the meaning of samples. How many times has an undesired result obtained from testing a sample been discarded because "there was something wrong with the sample"? Yet the adequacy of the sample is rarely questioned if the result from its test is favorable. Different results can be expected from the evaluation of different samples from the same lot of material. The degree of this difference and the probability of its occurrence can be computed provided the necessary information is available.

The number of defective pieces found in a sample, taken at random from a lot containing defective pieces, is a matter of probability. Statements of probability apply to the long-run or average situations. If a well-balanced coin is flipped, the probability of getting a "head" is the same as of getting a "tail" or one-half. There are two things which can happen; one will happen and one will not. The probability of drawing one particular card, say the ace of spades, from a deck is $\frac{1}{52}$. The probability of not drawing it is $\frac{51}{52}$. Suppose that a head is found on the first flip of a coin. Does that mean a tail will be obtained on the next flip? Not necessarily, since the probabilities of obtaining a head or a tail on the second flip are still equal. The "long run" results of flipping the well-balanced coin should approach 50% heads and 50% tails. The long-run results of combining two flips of the coin should approach these proportions:

2 heads	25%
1 head and 1 tail or 1 tail and 1 head	50%
2 tails	25%

If a head is obtained on the first flip, then the probability of obtaining heads on both flips is $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$ or 25%. The probability of getting a head, then a tail, is $\frac{1}{4}$ as is the probability of getting a tail followed by a head. These two sequences give the same final result, one head and one tail, and its probability is found by adding the probabilities of the two ways of producing the result. It will be noted that the total of all the probabilities in the table above, 25%, 50% and 25%, add to 100% or 1.

The example of flipping the coin illustrates two basic manipulations of probability calculations which apply to sampling problems: (1) Multiply the probabilities of things which *must* happen to produce a result, and (2) Add the probabilities of the various ways in which this result *can* be obtained. Further, the sum of the probabilities of all the things which can happen must equal 1. This statement of these rules is undoubtedly over-simplified and should be checked with similar, but precisely worded, statements in standard text books.

As with many other problems, the solution of the coin flipping problem and of sampling problems, in general, can be found by using a mathematical equation:

$$(h + t)^n = 1$$

where h is the fraction of heads in the sample
t is the fraction of tails in the sample
n is the sample size

If, as in the coin example, $h = t = 0.5$ and $n = 2$ flips,

$$(h + t)^2 = 1$$
$$h^2 + 2ht + t^2 = 1$$
$$0.25 + 0.50 + 0.25 = 1$$
$$(h) \quad (h + t) \quad (t)$$

The probabilities for 4 flips:

$$(h + t)^4 = 1$$
$$h^4 + 4h^3t + 6h^2t^2 + 4ht^3 + t^4 = 1$$

which is interpreted:

h^4 or $(0.5)^4$ probability of getting 4 heads
$4h^3t$ or $4\ (0.5)^3 \times (0.5)$ probability of getting 3 heads, 1 tail
$6h^2t^2$ or $6\ (0.5)^2 \times (0.5)^2$ probability of getting 2 heads, 2 tails
$4ht^3$ or $4\ (0.5) \times (0.5)^3$ probability of getting 1 head, 3 tails
t^4 or $(0.5)^4$ probability of getting 4 tails

In quality control work, this equation is written:

$$(p' + q')^n = 1$$

where conventionally, p' is the fraction defective in a lot, and q' is the fraction good in a lot. p' and q' are assumed to be or are known quantities in contrast to p and q indications from a sample.

Returning to the simple sampling plan previously discussed, if a lot is 1% defective, or $p' = 0.01$ and $q' = 0.99$ and a sample of 100 is taken:

$$(0.01 + 0.99)^{100} = 1$$
$$p' \quad q'$$

and the probability of finding 0 defects (all 100 good) in the 100 is 0.99^{100} and of finding 1 defect in the 100 is $100 \times 0.01 \times .99^{99}$

the probability of finding 0 is 0.366
and the probability of finding 1 is 0.370

the probability of finding 1 or less 0.736

Thus for the plan $n = 100$, $c = 1$ the probability of acceptance of a lot having 1% defective is 0.736 (and for rejection of that lot 0.264).

The working out of probabilities by the methods shown (called binomial expansion) can become very tedious as sample sizes (n) and acceptance numbers (c) increase. Fortunately, tables or curves giving probabilities have been prepared which represent sufficiently good approximations for practical use. These tables and graphs present results of the summation of the terms of Poisson's exponential binomial limit. A table of this type is published by Grant,[1] and the graphical representation has been noted in several texts on statistical quality control.

The Poisson approximation does not serve for calculating probabilities when extremely small samples are used (less than 16), but is sufficiently accurate for most calculations of probabilities of sampling plans. The binomial expression is used for small samples. Probabilities are given in terms of c or less and np'. c is the number of defects or defectives, n is the sample size and p' is the fraction of defects in the lot. Grant's table carries np' to 25 and c to 43. Molina's tables[2] are more extensive, but are published in a somewhat different form than that used by Grant. The conversion is not difficult. The calculation for the probability of any given occurrence c is made by use of the formula:

$$\frac{(np')^c}{c!} \times e^{-np'}$$

where n is sample size and p′ is fraction defective in the lot, e is the natural logarithmic base (2.7183) and c is the number of occurrences. c! is c × (c — 1) × (c — 2), ... × (c — c + 1). This equation gives values for individual levels of c. To find the probability of "c or less," add the probabilities for each value of c (including 0) up to and including the value of c of particular interest.

Table I gives results of limited calculations using the Poisson function.

TABLE I

Probability of Finding c or Less Defectives in a Sample of Size n From a Lot of p′ Fraction Defective (From Poisson Function)

c	0	1	2	3	4	5	6	7	8
np′									
1.0	.368	.736	.920	.981	.996	.999	1.000		
2.0	.135	.406	.677	.857	.947	.983	.995	.999	1.000

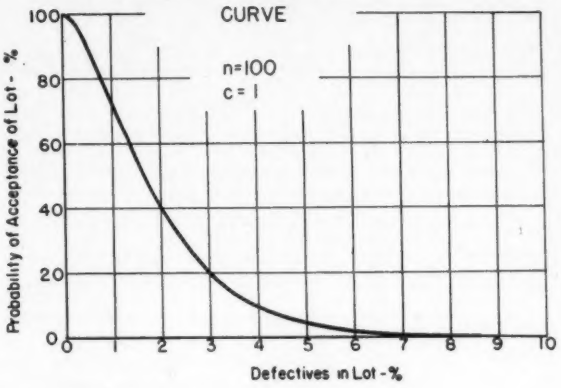
This discussion of probability has been introduced to justify the conclusion that there is nothing wrong with a sample if it does not perfectly represent the quality of the lot from which it is taken. It follows that if successive lots of equal quality are submitted, a sampling plan will accept some of these and reject others. This condition is a weakness of decisions based on samples but seems to be inevitable. Some understanding of probability and probability calculations is required for the interpretation of sampling plans. However, it is necessary to introduce another subject, briefly, before taking up the matter of sampling plan interpretation.

The sampling plan n = 100, c = 1, which has been used for illustrations to this point is known as a "single" sampling plan because the decision to accept or reject is based on one sample only. Double sampling plans may be used to reach the decision. These are commonly denoted $n_1 = 70$, $c_1 — 0$, $n_2 = 140$, $c_2 = 2$, as an example. This double sampling plan is read "take a (random) sample of 70 pieces, and accept the lot if 0 defectives are found. If 1 or 2 defectives are found in the sample of 70, take a second sample of 140, and accept the lot if a total of 2 or less defects are found in the combined samples. Reject the lot after the first sampling if more than 2 defectives are found, or after the second sampling when the total defectives found exceed 2." It will be seen that the results of the first sample are not ignored when a second sample is taken. Frequently the second sample is twice the size of the first sample but this is not always true. Also, in some special cases, resampling may be defined differently. As an example of this, the above plan may have been written to reject the first sample if more than one defective is found, which would mean that resampling is permitted only if one defective is found, with the total number of defectives allowable in two samples still remaining at 2, as shown.

A multiple or sequential plan may be used instead of single or double plan. Such plans usually employ a series of samples of constant size with the numbers specifying acceptance and rejection increasing as additional samples are taken. There is no particular limitation on the number of steps or individual samples taken, except for the natural limitation of lot size.

FIGURE 1

SAMPLING PLAN OPERATING CHARACTERISTIC CURVE



Having indicated that there are three general types of sampling plans, a return may be made to the interpretation of sampling plans and the part that probability calculations play in this interpretation. A curve showing the relationship between the per cent or fraction of defects or defective pieces in the lot (p′) and the probability of acceptance of the lot is known as an "operating characteristic curve" for a plan having sample size n and acceptance number c. Figure 1 shows such a curve for the single sampling plan n = 100, c = 1. The location of two of the points on this curve can be derived from the information contained in Table I. np′ for 1% defectives is 100 × .01 = 1.0. c or less = 1. Thus, the probability of a lot of 1% defectives being accepted under the sampling plan is .736 or 73.6%. np′ for 2% defective is 100 × 0.02 = 2.0. The probability acceptance for np′ = 2 and c or less = 1 is 0.406 or 40.6%. Other points on the curve are derived from more extensive tables or calculations.

The calculation of the operating characteristic curves for double sampling plans is more complicated but still not difficult. The plan mentioned previously was $c_1 = 70$, $n_1 = 0$, $c_2 = 140$, $n_2 = 2$. Again using Table I, for np′ to equal 1 when n = 70, p′ must equal 0.0143 or 1.43% defective (70 × 0.0143 = 1.0). For c = 0, the probability is 0.368. This is the probability that the lot will be accepted on the basis of the first sample. The lot will be rejected on the first sample if c is greater than 2. Thus the probability of rejection on the first sampling is 1.000 — .920 or .080, 8.0%. The probability that the second sample will be required is 0.920 — 0.368 or 0.552. The np′ for the second sample is 140 × 0.0143 = 2.0. There are two ways in which the lot will be accepted, if resampled:

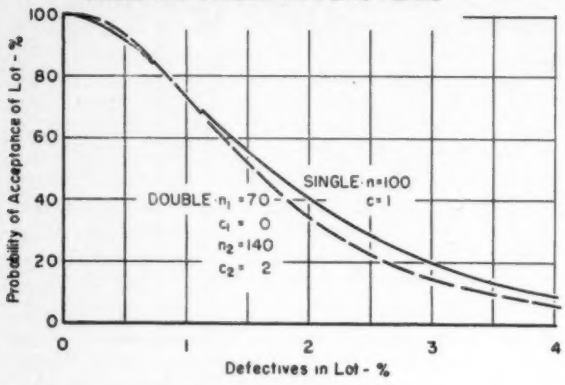
	Defectives Found	
1st sample	*2nd sample*	*Total*
1	1 or 0	2 or less
2	0	2

When np′ = 1.0 the probability of finding one defective piece in the first sample is 0.736 — 0.368 = 0.368.
(1 or less) (0)

The probability of finding 1 or 0 defectives in the second sample is 0.406 (np′ = 2.0) so that the probability

FIGURE 2

OPERATING CHARACTERISTIC CURVES
SINGLE AND DOUBLE SAMPLING PLANS



of this sequence of events happening is

$$0.368 \times 0.406 = 0.149$$

The probability of finding two defective pieces in the first sample is $0.920 - 0.736 = 0.184$, and of finding 0 in the second is 0.135. Their product:

$$0.184 \times 0.135 = 0.025$$

Since this event of passing the lot on the second sample can happen in two ways, the respective probabilities are added:

$$0.149 + 0.025 = 0.174$$

Thus, the probability of acceptance by the sampling plan is:

First sample	0.368
Second sample	0.174
Total	0.542

at a p′ of 0.0143 or 1.43%.

The operating characteristic curves for the two example sampling plans discussed are shown in Fig. 2 over the range of p′ to 0.04 or 4.0%.

A similar process may be used for calculating the operating characteristic curves of multiple or sequential sampling plans, but cannot be recommended because of the work involved. It is understood that methods of dealing with multiple sampling problems are covered in a Columbia University publication.[3]

The methods of calculating probabilities which have been outlined assume that the lot or shipment is not altered by withdrawal of the sample. If the sample represents a significant proportion of the lot, it is desirable to refine the calculations. The refinement is based on the idea of piece-by-piece withdrawal of the sample and the effect that this withdrawal has on the fraction defective of the remainder of the lot. The concept is illustrated by stating that the probability of drawing any ace from one deck of cards is $\frac{4}{52}$. If the first card drawn is an ace and if it is not returned to the deck, the probability of drawing an ace on the second draw is $\frac{3}{51}$. Likewise, if the first card drawn is not an ace and this card is not returned to the deck, the probability of drawing an ace on the second draw is $\frac{4}{51}$.

The operating characteristic curve of a sampling plan warns the vendor of the likelihood of rejection of shipments having the quality level he customarily produces. It should be evident that the vendor should be able to supply goods at a quality level which corresponds to an acceptance probability of over 90%, as a practical matter. The operating characteristic curve warns the consumer of the risk he is taking of accepting lots of inferior quality. He must realize, while the sampling plan may be altered to require a high quality, such alteration may reduce the available supply of material or increase the production costs of his vendor.

Operating characteristic curves (and the sampling plans from which they are derived) seem to be designated in a number of ways. One method involves a statement of allowable per cent defective and a probability. The plan described by Fig. 1 might be denoted as having an acceptable quality level (AQL) of 0.38% at a producer's risk of 0.05. This producer's risk is the probability of rejection of lots of 0.38% defective. The same curve may also be characterized as having a lot tolerance fraction defective (p_t) of 3.9% at a consumer's risk of 0.10 (Pc· the probability of acceptance of quality of lower than p_t). Other plans may be denoted by AOQL (average outgoing quality limit). The AOQL is the maximum possible value of the average fraction defective in lots accepted by a sampling plan if the rejected lots are given 100% inspection and all defective pieces are removed. Since there is a difference in viewpoint between a vendor and a consumer and since the operating characteristic curves for different sampling plans can pass through the same point but have different values at other points, it is suggested that the operating characteristic curve for any plan be studied before the plan is adopted.

Figure 3 shows the operating characteristic curves for four single sampling plans in which c is 1% of n. They are approximately equivalent at p′ = 0.009 (defectives = 0.9%), but are quite different at other points. These curves illustrate the effect of sample size on operating characteristic curves. The use of larger samples results in a more nearly ideal situation so far as control of quality is concerned. An ideal curve is one which is vertical. The use of larger samples gives better control, but with added inspection cost. As lot sizes are increased, this added inspection cost can be justified.

When a sampling plan is needed, it is probably better to select one of the several plans which have been published. The exact plan which will be adopted will depend upon the purpose for which it is intended and the circumstances surrounding its use.

The Dodge-Romig[4] Sampling Tables provide for single- and double-sampling plans based on (1) lot tolerance fraction defective at a consumer's risk of 0.10 and (2) constant AOQL (average outgoing quality limit). The Dodge-Romig tables are designed to require the minimum of total inspection of samples plus (100%) inspection of rejected goods. A knowledge of process average is required for the most effective use of these plans, but they can be put into effect without an exact knowledge of process average. Generally, process average is calculated from the number of pieces examined and the total number of defective pieces found. When a double sampling plan is used, only the results from the first of the two samples is used in calculating the process average. For purposes of determining process average, the first sample is given a complete inspection, even though rejection has been indicated during the course of examination. It would seem that the Dodge-Romig AOQL plans should

be considered for in-plant and final inspection operations. AOQL may have little meaning in connection with inspection of incoming material if rejected lots are returned to the vendor who may or may not carry out 100% inspection on them.

Sampling tables have been prepared by the Statistical Research Group of Columbia Uinversity[5]. These tables provide plans for single-, double- and multiple sampling. The plans are generally calculated to provide about 95% acceptance for the stated AQL (acceptable quality level). Operating characteristic curves illustrating the various plans are given. There is a statement of the AOQL for each plan. As a practical matter, the choice of AQL is usually a comprise between the quality desired and the quality available.

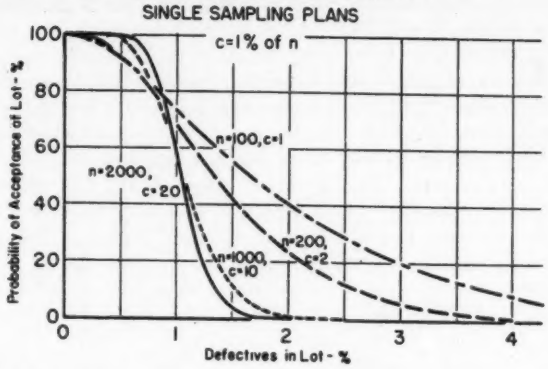
Military Standard Tables[6] are prepared along the same general lines as the Columbia University Tables. However, the AQL designation does not correspond to a constant probability of acceptance, but seems to range between about 85 to 99%. Operating characteristic curves illustrating the plans are presented.

Most sampling schemes provide in some form or other for reduced and tightened inspection. Reduced inspection may be instituted for items and vendors whose inspection histories show consistently good quality performance. Tightened inspection may be applied to a vendor or item whose general performance is poor. Reduced inspection with reduced cost is logical from both the satistical and "common sense" point of view for goods of high quality from a reliable producer. Tightened inspection provides greater assurance against the acceptance of low quality goods from a producer who has a history of unsatisfactory quality performance. The tightened inspection encourages the producer to improve his quality by temporarily increasing the proportion of rejections.

Whether a single, double or multiple sampling plan is chosen is to be decided after considering the advantages and disadvantages of each. A single sampling plan usually requires examination of more pieces, is psychologically poor because of its "one chance" nature, is simplest to sample, administer and record, and usually tells the most about process average. A double sampling plan usually requires the examination of fewer pieces, is psychologically better, is somewhat more complicated to operate and tells less about the process average. A multiple sampling plan usually requires examination of the fewest pieces, is psychologically less satisfactory because of its tendency to put off the decision, is the most complicated to operate and tells the least about the process average. The double sampling plan equivalent to some single sampling plan will have a smaller first sample than the sample of the single plan. When these plans are applied to the inspection of lots of very high or very low quality —lots of high acceptance or rejection on the basis of the first sample—fewer pieces per lot have to be inspected using the double plan. The double plan requires more inspection effort for lots of intermediate quality. However, the submission of lots of relatively high quality is usually assumed and, under this condition, the double sampling plan offers advantages in reducing sample inspection costs. A similar conclusion may be reached with respect to multiple sampling plans.

If all defects which are likely to be encountered are of equal seriousness, then an AQL may be chosen which contemplates the summation of the likely occurrence, and

FIGURE 3
OPERATING CHARACTERISTIC CURVES
SINGLE SAMPLING PLANS



one sampling plan used for the inspection. As a general proposition, defects are classified according to the certainty and seriousness of their effect upon the utility of the product or of the material. Headings such as "critical", "major" and "minor", or merely "major" and "minor" are terms which are sometimes applied to these classes. The titles should be sufficiently descriptive. If each of several different defects is equal in its seriousness and certainty of causing failure, there is no reason why the total of all these defects should not be added together in the inspection. However, some consideration should be given to inspection on the basis of defects or defective pieces. Defective pieces, or "defectives", implies that a piece may contain more than one defect but be considered as defective only once. This is the proper concept to follow when there may be a common cause for several different defects. A "minor" defect may become "major" or even "critical" depending on degree. Specifications or limit samples are needed for definition when degree is involved. When defects are classified and acceptance criteria are applied to each class, the probability of acceptance of the lots is represented by the product of the acceptance probabilities of each inspection. This will be recognized as one of the "rules" of probability mentioned earlier.

Different non-destructive inspections and tests may be carried out on the same samples. Destructive testing, even though carried out on a go-, no-go basis may be time-consuming and therefore expensive. Samples smaller than those taken for visual inspection may be justified and are frequently used.

Not the least important part of accepting sampling is the sampling process itself. The probability calculations are based on the assumption that a random sample has been taken. The consumer usually knows little about the homogeneity of the lots he receives. He is forced to get as nearly a representative sample as possible The use of tables of random numbers is helpful in selecting a sample on a random basis. However, practical considerations resulting from inaccessibility of portions of shipments before unloading and from packaging in cartons usually result in the adoption of sampling procedures somewhat less than ideally random. The sampling practices which depart from truly random will cause the samples to misrepresent the lot, favorably or unfavorably, more than is anticipated from probability calculations based on the assumption of random sampling. Therefore,

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GLASS DIVISION MEETING DRAWS LARGE ATTENDANCE

In all respects—except for raw weather and a drizzle that made golfing uncomfortable—the Fall Meeting of the Glass Division of the American Ceramic Society held October 10 and 11 at Bedford Springs, Pa., was a great success. The Division returned to this resort hotel, where the Fall Meeting was held in 1948, to enjoy the excellent auditorium and the ample space in lobby and rooms for committee meetings. The log fire in the lobby was a comforting feature to offset the gloom and chill of the weather.

Charles S. Pearce, General Secretary of the Society, was on hand with some able assistants from the Columbus Office: Messrs. Ohrstedt, Reed and Kraschman. They took care of registration and other arrangements that made the meeting operate smoothly.

Registrations included 176 men, 45 of them accompanied by wives. It is safe to say that almost all of the important glass companies east of the Mississippi were represented. The increasing numbers of younger men attending these meetings is encouraging. It points to the continuing growth of the Division and its attractions for the newer technologists, as well as to the progressive attitude of employers in sending relatively large groups of representatives to such gatherings. The friendly and cooperative spirit that has always characterized the Glass Division was as strongly apparent as ever.

Chairman Leonard G. Ghering, Preston Laboratories, called his Committee C-14, A.S.T.M., together on Thursday evening. This innovation, the selection of an early time ahead of the technical sessions instead of after them, proved to be a successful move. Twenty members were in attendance, which is a comparatively large number. The meeting was unhurried and the men were all fresh for the reports and discussion of future work. Nearly all the sub-committees were represented by chairmen or members prepared to report. The present year is the fiftieth for A.S.T.M. and the eighteenth for C-14.

This Committee C-14 serves as the Standards Committee of the Division and its liaison with organizations on standards, abroad as well as in the U.S.A. Some of its more active projects deal with analytical methods, durability of containers and strength measurements.

The sub-committee on Nomenclature and Definitions might be presumed to have finished its work, having published its "Glass Glossary" a few years ago. Nevertheless, Chairman Harry H. Holscher, Owens-Illinois Glass Company, called his group together for an extended meeting on Friday morning. It appears that second and even third thoughts have been given by several technologists to the term "strain point." Some of them feel quite sure that the present linking of strain point to a specific viscosity is a mistake. A view is also held that any attempt to fix strain point may be a mistake; or, at best, only an arbitrary definition that cannot satisfy everyone is possible.

Attention was directed to an excellent compilation of "Glassware Definitions" by National Better Business Bureaus, Inc., in cooperation with the American Glassware Association. The object of these definitions is to promote accuracy and uniformity in describing glassware and its various treatments and decorations in the interest of trade practices. The Committee hopes that Glass Division members will examine these definitions, as well as the published Glass Glossary, and suggest to the Committee places where more harmonious and accurate phrasing may be accomplished.

On Friday morning, about one-fourth of the registrants braved the drizzle, the soggy ground and the brooks that claim many balls and went golfing on the excellent 18-hole layout. Part of the urge was furnished by the splendid assortment of prizes on display in the lobby. Of the results, more appears later. The women, with much less in the way of prizes to hope for, nevertheless had a lively and pleasant morning of bridge.

Arrangements for the technical sessions were excellent. Screen, lantern, seating and p-a system were all that could be desired. However, some slides are still being made with so much information in so much fine print upon them that opera glasses and much time would be required by a member of the audience to discover the full import of the lore so optimistically presented. And still there are presenters of papers who talk confidentially to themselves, to the screen or, at most, to the front rows of the audience, avoiding the microphone as though it might interrupt by talking back.

Chairman Fay V. Tooley, University of Illinois, presided at most of the sessions, relieved at intervals by Vice-Chairman Norbert J. Kreidl, Bausch & Lomb Optical Company, and Secretary Fred L. Bishop, American Window Glass Company. The program had been ably put together by the committee headed by W. H. Manring, The Calumite Company. His helpers were T. G. Pett, Bausch & Lomb Optical Company, and F. W. Mowrey, American Window Glass Company.

No one is more capable than Professor Alex Silverman in giving a retrospect of glass in the fifty-year period now ending. He has seen it all, and he has participated in much, when the changes in glass technology during that time are considered. When Dr. Silverman began in glass in 1902, only seven scientific men were employed in the whole industry, and only three of these are now alive.

From rule-of-thumb batches to fine-structure studies; from mouth-blown cylinders to continuous drawing of sheet glass; from the slow hand methods to speedy machines of today, the Professor has watched it all and shared in the developments, and reports them in a manner entertaining.

Dr. Frank W. Preston, Preston Laboratories, himself can always come up with a whimsical title that arouses curiosity as he launches into a mathematical discussion. "Annealing as a Problem in Genetics" did not pretend that internal strains and racial strains were in any way similar. However, humans who leave descendants and how many, and those who do not, can be calculated as to numbers by Dr. Preston's favorite theorem—once called Poisson's—and he made the same sort of calculation apply to the survival of strain as time goes on.

The Specific Heat of Vitreous Silica was investigated by Smyth, Skogen and Harsell, of Rutgers University, and Professor Smyth reported. The curve seems to be a decent one up to 1000°C. or so, and then takes off up-

ward in a manner anomalous. Your reporter was left puzzled when explanations involving electrical waves and their scattering in crosswise directions were presented. Close reading of this paper when it is published is to be recommended.

Another team from Rutgers, made up of Smyth, Londeree and Leroy, had worked on the "Compressibility of Vitreous Silica." George E. Leroy gave the paper. As one might imagine, vitreous silica is not easily compressible, and it is easy to believe that pressures as high as 12,000 megabars (about 180,000 pounds per square inch to us boys, Rollo) were used in the experiments.

The queer part seemed to be that the silica glass showed increased compressibility as pressures increased. The explanation offered involved a consideration of the configuration of silicon and oxygen atoms, and, in particular, the kinking of the line of direction between silicon and the second of its oxygen neighbors. Of those curious things called "bonds," were some sort of rigid rods and a bending of a kind of tiggle joint took place, it would bend easier the more it bent—whoa! we're off the deep end!

Dr. Frank R. Bacon, of Owens-Illinois Glass Company, gave an interesting report on the effect of treating amber glass to soaking heat at various temperatures. Transmittance was increased by soaking at 1100°-1200°C., but was reduced at 950°. No explanation was insisted upon, but some structure change was suggested. Changes of density were parallel to changes in color. Dr. Bacon was complimented by the chairman, and drew a round of applause for his slides which were clear and uncrowded, with lettering and numbering large enough for easy reading.

"Further Evidence Against the Orientation of Structure in Glass" was presented by Ralph T. Brannan, of Owens-Corning Fiberglas Corporation. He performed a semi-micro determination of the torsion modulus of elasticity on a fine fiber and from the derived value of Poisson's ratio, 0.18, decided that the value was normal within the experimental error. If the fine structure of the glass had been oriented by the drawing operation, an abnormal value for Poisson's ratio would have been found. Mr. Brannan's slides were exceptionally good. As Dr. Bacon gracefully remarked, "I held the record for about ten minutes."

The dinner on Friday evening taxed the capacity of the dining room. Present were five past presidents of the Society, who were called up for recognition: Flint, Hostetter, Kelsey, Tillotson and Lillie. The Chairman also introduced his fellow officers and the heads and members of the Division committees. A visitor from England, Mr. David Osborne, of the staff of the laboratory of R. W. Douglas, G.E.C., was introduced. Mr. Osborne responded by remarking that the prevailing kindness and hospitality of Americans make his most important impression of America.

Presentation of the Forrest and Meyer Awards was the formal after-dinner business. Trustee K. C. Lyon presented the Frank Forrest citation and accompanying check to Dr. Howard O. McMann, Scientific Director of Arthur D. Little and Company, for his paper on "Thermal Character and Thermal Radiation of Glass," appearing in the *Journal of the Optical Society*, June 1950. Dr. Lyon announced the winning of the S. B. Meyer Jr. Award by Dr. J. V. Fitzgerald, Research Laboratory of Pittsburgh Plate Glass Company, for his series of papers on "The Anelasticity of Glass," published in the *Journal of the American Ceramic Society*, October, November and December 1951. In the absence of Dr. Fitzgerald, Dr. Lang, his colleague, received the citation and prize.

It will be recalled that these awards were established by the Preston Laboratories in memory of two young glass technologists killed during Word War II.

Later in the evening, a group concerned with our participation in the International Commission for Glass met to formulate a plan for a continuing committee to advise with the Trustee of the Division on that participation.

Hugh L. Kline, Corhart Refractories Company, then presented the golf prizes and also a list of door prizes. These last were added to use up the generous lot of prizes accumulated by the efforts of Mr. Kline.

Winners of door prizes were F. R. Matson, J. C. Keaney, Geo. R. Macalan, T. B. Montgomery and W. F. Gilluly. 49 golfers waded through a soggy course. The 10 top golfers, with gross scores, were: J. P. Poole, 82; R. O. Hummel, 83; K. Conrad, 85; E. E. Humphrey, 85; R. F. Dowling, 90; G. Kellenberger, 91; K. M. Henry, 91; W. H. Otto, 93; F. Pinotti, 96; and R. W. Morgan, 96.

Saturday morning brought more papers. J. H. Toulouse, Owens-Illinois Glass Company, argued effectively for Statistical Methods of Quality Control in the Container Industry. E. B. Shand presented "Experimental Study of the Fracture of Glass, Part I." Both of these papers will form welcome additions to the literature of glass.

A beautifully illustrated address on "The Measurement Scales for Color and Appearance of Glass Materials" was given by Richard S. Hunter, Hunter Laboratories, Falls Church, Va. It was the type of entertaining and informing lecture that must be "seen" to be understood.

The contribution from the National Bureau of Standards, by Shartsis, Capps and Spinner, was presented by Webster Capps. "Density and Expansion of Alkali Borates" was the title of a paper that furnishes authoritative data on these important members of glass, glaze and enamel compositions.

Fully 35 members remained for the brief business session. The new rules proposed for the establishment of a committee on the International Commission was duly presented and ordered out for letter ballot. A report on Standard Samples brought out a suggestion for circulation of these samples to selected laboratories for the establishment of data on physical and chemical properties.

OWENS-CORNING ANNUAL REPORT BEST IN GLASS INDUSTRY

Owens-Corning Fiberglas Corporation's annual report for 1951 has been judged the best in the glass industry. Announcement that the Toledo firm's report had won the bronze "Oscar of Industry" given by *Financial World* was made by Weston Smith, Executive Vice President of the publication.

Runner-up to the O-C report was that of Pittsburgh Plate Glass Company, while Anchor Hocking Glass Corporation was third.

THE GLASS SECTION AT THE PACIFIC COAST REGIONAL MEETING

The Seattle Meeting was a success. Edward Burkhalter, Chairman, opened the convention of the fifth Pacific Coast Regional Meeting of the American Ceramic Society, October 16-18, with an "Address of Welcome," and President W. E. Cramer transmitted greetings from the American Ceramic Society. The keynote address on the subject "Small Business," by L. R. Whitaker of Columbia, South Carolina, was highlighted by constructive suggestions and lively humor. The total attendance of 250 testified to interest in the technical sessions which included 42 papers and discussions.

Structurally, the meetings followed the usual pattern, and the evening functions included an alumni dinner, an informal reception and banquet. Of particular value was the Education-Industry luncheon, at which time prominent educators and industrialists discussed the need and means for getting high school students interested in engineering courses, and particularly in ceramic engineering. The 30% drop-off in B.S. degrees to be granted in ceramics for 1953, resulting in an estimated total of 130 graduates for the combined United States and Canada area, shows how critical this problem is for the ceramic industry.

The Glass Section program was well balanced and diversified. Harold Baque of Corhart Refractories Company discussed stones in glass, and supported his remarks by means of fifteen color slides. After reference to A. K. Lyle's classification of the origin of stones in continuous tanks, Mr. Baque discussed four factors that contribute to the formation of stones; namely, time, flame velocity, tank pressures and refractories. He made suggestions as to what can be done to reduce stones, and indicated trends toward the future.

After stating that flame velocities are usually from 20 to 30 ft. per second or about 20-miles per hour, Mr. Baque suggested that tank pressures should be kept low so as to minimize the seepage of condensable chemicals into the refractory structure. Port necks are probably the largest contributor of stones, with the type of firing, i.e. end-fired in contrast to side-fired tanks, being a very important factor.

At present there is much interest in both bottom and sidewall insulation as well as in the extended use of basic checker brick.

Ray Davis, Jr., of General Refractories Company presented R. G. Abbey's paper, "Refractory Trends in the Glass Industry," using numerous slides to demonstrate the points in question. After stating that two-year campaigns are now common at loads as heavy as 5 sq. ft. per ton, Mr. Davis pointed out that in one instance the regenerator superstructure remained in operation for 6 years. Magnesite bonded checker brick when used in conjunction with basic superstructures are giving industry extended regenerator life. The use of cased brick, as well as magnesia chrome bonded brick, was also included in the discussion.

As a final contribution to the combined session of glass and refractories, James C. Hicks showed a sound color film entitled "Refractories from the Sea," a contribution from Kaiser Aluminum and Chemical Company. The manufacture and uses of "Periclase" checker brick were stressed, as well as application in the glass and steel industries.

Allen Erickson of the Northwestern Glass Company was chairman of the second and last session of the Glass Section, which took the form of four discussions.

R. J. Campbell of the University of Washington discussed work in progress on the analysis of raw materials for iron. This method consists in forming 3/8" x 3/8" x 3" bars from glasses containing the raw materials under consideration, and measuring the "iron" concentration by means of a Beckman Spectrophotometer. This procedure is used at the local glass plant for evaluating sands, and has included both soda-lime as well as lead-based glasses. The range was stated to be 0.005% to 0.32% Fe_2O_3.

A discussion of "Special Glasses and Their Use in Gamma Radiation Shielding" was provided by Larry Penberthy of the Penberthy Instrument Company. Glasses containing over 80% PbO are used for this purpose, thereby providing protection from those very penetrating rays. This important contribution of glass to modern science was evident from the demonstration.

Edward S. Campbell's comments on electro-melting at the Northwestern Glass Company included a brief summary of the start of this project which has resulted in two tanks that are in continuous operation, producing good quality containers.

Northwestern's first all-electric glass melting unit was constructed in 1945 by Y. R. Cornelius for amber glass production at a pull of 18-tons per day. (See Electric Glass Melting by Y. R. Cornelius, THE GLASS INDUSTRY, February 1948, page 71.) Good quality glass was obtained for about 6 months following which some of the electrodes floated to the surface and hot spots appeared along the sidewalls. These weaknesses were corrected in the second unit which remained in operation for 12 months. Subsequent rebuilds were based on taking advantage of earlier experiences with the result that by 1950 a practical unit was in operation producing 25 tons of commercial glass daily.

At the present time Northwestern is operating two units, each pulling 20-30 tons of amber glass per day without overloading either tank. Under local conditions operating costs are apparently not prohibitive and the product is claimed to show above average homogeneity with high production efficiency. Results point to electricity as being the ideal form of heat in areas of low cost power. Mr. Campbell is to extend application experimentally to his flint tank, a matter which the entire glass industry will follow with a great deal of interest.

Finally, Larry Penberthy's subject, "Electro-melting of Glass and its Effects on Homogeneity," took the form of an open forum type of discussion, the objective being to derive some useful and practical explanation of the flow of glass within an electrical melting unit, which is a relatively closed system as compared to the regular type of glass tank. The approach to the problem was novel in meetings of this type and may point the way towards wider use of well-directed open discussions of this nature.

A visit to the electro-melting units at the Northwestern

(*Continued on page* 616)

COLORATION OF GLASS BY RADIATION

By KUAN-HAN SUN and NORBERT J. KREIDL

PART II

Historical Background on the Coloration of Glass by Radiations

Faraday[65] was generally credited as the first to describe the deepening of purple color of Mn-containing glass by the sun. Since the use of glass may be dated back before Faraday's time and the presence of Mn in glass was rather common, it would not be surprising if earlier references to the solarization effect may be found. The coloration of glass by radiations from the radioactive materials, however, must have been observed after the discovery of the radioactivity by H. A. Becquerel in 1896. Since glass vessels have always been among the most indispensible articles in a laboratory, it did not take long to discover or to notice the coloration of glass by radiations from radioactive materials. For example, Mme. Curie[46] reported the effect of coloration as early as about three years after the discovery of the radioactivity. Beilby[19] at the turn of the century also noticed and studied the luminescence, thermoluminescence, discoloration, and removal of discoloration by heating, of glass exposed to the radiations of radium. A comprehensive review on solarization induced mostly by ultraviolet radiations has been given by Weyl[186] and on coloration of glass by radiations by Lind[105], Monk [116], Otley[125] and others. A fairly comprehensive bibliography on the coloration of glass by radiations is given at the end of the present study.

The effects of different types of radiations on glass were recognized relatively early. For example Livingston and Nurnberger[106] observed that while the amber or brownish coloration produced by x-rays or γ-rays from radium was quite uniform throughout the glass body, the α-rays from radium produced a thin skin of only about 0.04 mm of very intense coloration as was also found by Rutherford.[143] The color produced by β-rays was intermediate in intensity as well as in penetration as compared with that from α-rays and γ-rays. The thickness of the layer was about 2.5 mm. These observations are in complete agreement with the discussions given earlier on the nature of various kinds of radiations. Early studies of Lind[103] were also of interest. Since then many investigations were noted. Perhaps the most comprehensive observations on the coloration of glass by γ-rays and neutrons were the recent studies by Monk[116] who has been largely responsible in the steering of development of radiation insensitive optical glasses in the Manhattan and AEC projects, even though the technical ideas involved were not necessarily of recent origin.

Among many things studied by Monk[116], a few may be mentioned for their particular interest. For optical glasses from crown to flint colored by γ-rays, it seems that a broad absorption peak near 3700 A occurs. For borate type of optical glasses containing Ba, La, Th, W, etc., such as those developed by the Eastman Kodak Company, there might be absorption peaks in the visible regions overlapping with each other. The most startling absorption peak was exhibited by a Corex glass near 4700 A. The Corex glass is mainly calcium metaphosphate. With neutron irradiation in a reactor, Monk found that boron-containing glasses darkened most readily on the surface with a depth of about one-half to one millimeter. This was called the edge effect by Monk and can be explained easily by the high cross section of B^{10} in boron for slow neutrons. Incoming neutrons are mostly absorbed on the edge or surface. The darkening is caused by the α-particles formed from the nuclear reaction. The α-particles have short ranges and are a very powerful agent for ionization and consequently coloration. Since the interior of the glass is thus protected from slow neutrons by the exterior, an edge or surface effect results. For fast neutrons, there is no preferential interaction with boron. As a matter of fact, the cross-sections for fast neutrons of all known nuclei are relatively small. One would not expect the surface effect in fast neutron exposure which agrees with Monk's findings. The surface effect probably will also be found in an enriched uranium-containing glass from slow neutron irradiation. Powell and Denvenport[133] observed that cadmium-silicate type glasses[112] resist coloration from very intense neutron bombardment (10^{18} neutrons/cm^2) better than the pyrex glass and other common glasses. The cadmium-silicate glasses containing boron color much easier.

No data are available as to the effect of direct bombardment by protons, deuterons and α-particles, of high intensity. The writers of this report bombarded a piece of lead phosphate glass containing about 60 weight % PbO with about 10^{14} per cm^2 15 mev deuterons about three years ago. While the heat of the beam melted down the glass, the glass was apparently not colored. The resistance of lead phosphate types of glasses to coloration was also noted in the works of Rothermel, Sun and Silverman[140], Hood[91] and Monk.[116] Penberthy has also made practical glasses from these ingredients. It has also been observed by the writers that ordinary glass as well as pure silica glass developed a dark skin and turtle cracks on the surface upon long bombardment by proton beams of a few mev energy. It is also reported that Pyrex glass fell to pieces upon bombardment by fission fragments.

The production of color or coloration by radiations is, in general, undesirable because it renders the glass useless as an optical element. However, advantages have been taken of the fact that the color changes produced by radiations may be used as a means to measure the intensity of radiations. That introduces the subject of glass dosimetry. Since dosimetry is usually related to biological purposes, the intensity of radiations that is of interest is in a much smaller order of magnitude than that of coloration. In general, the range of intensity is between a small fraction of one roentgen to several hundred roentgens. However, for sterilization purposes dosimeters up to 10^6 r may be still useful. The first dosimeter glass was developed by Weyl, Schulman, Ginther, and Evans[194, 147-9] in cooperation with one of the authors (N. J. Kreidl)[7]. It was essentially a silver-containing K-Ba-Al phosphate glass with the silver content of about 7% selected from a nearly equally efficient

range of 1-16%. When the glass is exposed to radiations, elemental silver appears to be produced upon absorption of an electron, which is detected through its fluorescence under ultraviolet irradiation. Alger and Levy[2, 3, 148] have cooperated on the further studies of this type of glass. The effect of radiations on glasses containing copper, silver, gold, palladium or other elements has been studied by Dalton[47, 48], Stookey[166-177], Armsted[10, 11] and others. The atoms of Cu, Ag, Au, Pd or other elements formed by reduction through the effect of radiations are allowed to migrate in glass at an elevated temperature, until the sizes of the metallic aggregates are large enough to be visible. Alternatively, the metallic atoms formed may serve as the nuclei for the crystallization of supersaturated phases, such as lithium or barium silicate, to produce opalescent effects. The Corning Glass Works has applied the photosensitivity effect to the artistic production of photographic glass prints as well as to the "machining"[177] of glass. It was found by Stookey that the portion of glass that contains the reduced metallic atoms or atomic aggregates are etched by acid many times faster than that containing none. Photosensitivity is thus a primary process in cutting or machining glass. The photosensitivity of silver-containing glass reminds the present writers of an early experience with a silver-borate glass containing about 45% by weight of Ag_2O. The glass was yellowish when freshly prepared, but assumed a mirror-like appearance upon standing in air for several weeks.

During the development of the silver-containing dosimeter glass, it was discovered by J. H. Schulman that the base glass, K-Ba-Al phosphate glass, colored easily by radiations without silver. Experiments by N. J. Kreidl and associates showed that a high potash content seems to favor coloration. They verified this experience at the much higher intensity range (10^5 r) encountered in the study of prevention of coloration in instrument glasses. Apparently, the formation of color centers is also an essential factor responsible for the coloration. This opens up a new line of investigation for glass dosimetry. The direct visibility of coloration is always more convenient than through fluorescence or other effects.

The foregoing remarks serve as a brief review of the historical highlights regarding the effect of radiations on coloration of glass. Attention will be turned now to the physical and chemical mechanisms as well as other features involved in solarization, photosensitization, color center formation and thermoluminescence.

Solarization and Photosensitization

The phenomena of solarization and photosensitization involve the processes of oxidation and reduction. Basically there are not many differences between these two phenomena. For convenience, one might indicate that solarization is a process that involves the production of colored ions through the oxidation or reduction of a polyvalent ion by radiations, while photosensitization is associated with the reduction of ions to the elemental state. The detection of photosensitization may be through the fluorescent effect of the elemental atoms or the coagulation of these atoms into visible aggregates. The oxidation and reduction processes are nothing but the losing and gaining of electrons which are provided by the effect of the passage of radiations as mentioned before.

The classical example of solarization is the formation of the purple Mn^{3+} through the oxidation of Mn^{2+} by losing an electron upon irradiation:

$$Mn^{2+} + h\nu = Mn^{3+} + e^-$$

The electron liberated wanders away and may be captured by other oxidizing ions or electron traps. Many investigators have accepted the idea that the electrons liberated in the above oxidizing process may be captured by Fe^{3+} ions in glass by the following reaction:

$$Fe^{3+} + e^- = Fe^{2+}$$

This, however, should be compared with the findings of Starkie and Turner[167] who discovered the reverse of the above reaction for iron ions during the exposure of glass to the ultraviolet radiations. The oxidation of Fe^{2+} by x- and γ-radiation in aqueous solution was also noted[206].

Another interesting example of solarization is the remarkable color change from green to purple of the vanadium containing glass described by Weyl, Pincus and Badger[190] and also by Upton[183]. The change of color which can be achieved by one hour exposure in the sunlight is ascribed as due to the following reaction:

$$V^{3+} + e^- = V^{2+}$$

The V^{3+} and V^{2+} are respectively green and purple. The electrons required in the above reaction are believed by many workers as to be supplied by cerium through the action of radiations:

$$Ce^{3+} + h\nu = Ce^{4+} + e^-$$

Cerium is usually added with vanadium in the making of this type of glass.

Some of the solarization reactions seem to be reversible at elevated temperatures. For example, Crookes[43], among many others, noticed the disappearance of the purple color in glass upon heating to the softening temperature.

The effect of the base glass on the solarization may be inferred from the work of White and Silverman[193] who found no coloration of silicate type glasses by ultraviolet radiations when Li instead of Na or K and Be instead of Ca are used in the base glass. Apparently tighter electronic bindings through covalent linkages are favorable in resisting coloration. This seems in agreement with the findings by Kreidl in his work on the glass dosimeter and prevention of coloration by gamma rays.

A wealth of information may be found in Weyl's review as mentioned above. Much experimental information may be found, too, in the work of Parmelee, Clark and Badger[128] who studied the coloration by x-rays of borax beads in which some 50 different chemicals including the compounds of Cr, Pb, Bi, Tl, Mn, etc., were added. Livingston and Nurnberger[106] and Klemm and Berger[98] made quantitative studies on the effect of x-rays and ultraviolet-rays on the transmission of glass.

Among the substances most sensitive to solarization is a glaze found by Parmelee and Badger[127]. A glaze "containing flint feldspar, whiting, boric acid, clay, lead, zinc, tin and rutile was found to darken after exposure to daylight for less than a minute." The light sensitivity is possibly due to Ti and Sn. A uranium containing glaze was also found to darken under daylight. Weyl[188, 189] and his associates have also made observa-

tions on the darkening of various substances including rutile and mechanical mixtures of chemical substances. Cohn and Goodeve[38] observed that antimony oxide with and without other agents changes color in a few seconds upon irradiation with ultraviolet radiations. The change of color of barium platinocynide from green to deep orange upon x-ray irradiation may be also mentioned in passing. The effect has been used in the dosimetry of x-ray therapy[31]. In connection with the utilization of the Sun energy, Mac Nevin[205] reported the color change in Ca Ti O_3 on exposing to light.

The search for more sensitive glasses for dosimetry will encounter the difficult problem of chemical durability as will be made clear later. Therefore, it seems advisable to attempt to develop a polyphase material in which one of the phases may be a glass or even an organic plastic to take the place of transparent and homogeneous glass. The development may be expanded as to include all radiation sensitive crystals, as well as glasses of poor chemical durability, which can be eventually covered or imbedded in a glass or a plastic. The protecting glass composition can be adjusted so that it will absorb ultraviolet radiations from the sunlight or artificial light source while at the same time x-rays or γ-rays may be allowed to penetrate. Compounds of Ti, Cb, Sn, Fe, Cr, V, Tl and other multi-valent elements should be studied with special attention. The unmatched experiences and comprehensive knowledge of W. A. Weyl on the subject as exhibited in his monograph on colored glass[186] will be particularly helpful in such a development.

Now we turn to the photosensitivity of glass. The photosensitive glasses developed today depend on the reduction of metallic ions of copper, silver, gold, palladium, etc., into metallic atoms. For example:

$$Ag^{+} + e^{-} = Ag$$

In the phosphate glass developed for the purpose of dosimetry, no reducing agent seems necessary. The electrons required are supplied by those set free by radiations. The unusual success of the silver-containing phosphate glass developed by Schulman et al depends not only on its high photosensitivity but also on the fact that the atomic silver produced is detected through a very sensitive process; namely, the fluorescence effect. The unique combination produces the unusually sensitive and satisfactory character of this material. In the photosensitive glasses developed by Stookey and others, a sensitizer, namely a cerium compound, is necessary, which according to Stookey, plays the role of reducing agent in supplying the electrons required to convert the metallic ions into atoms. The role of cerium is as follows:

$$Ce^{3+} + h\gamma = Ce^{4+} + e^{-}$$

It will be interesting to inquire if the phosphate type of photosensitive glass may not be used for the photographic and "machining" purpose.

Efforts are being made at the Corning Glass Works to detect the individual nuclear particles by their ionizations tracks in glass similar to those appearing in the photographic emulsion. If these efforts should prove successful, the problem of using glass as dosimeter for radiations will assume a very significant role.

So far, all the photosensitive glasses developed are not comparable in sensitivity with the photographic emulsions. This is because of the fact that in the latter case, once a small fraction of a silver halide grain is reduced, the whole grain is developable or reducible; thus a multiplication factor is achieved which has not been the case in photosensitive glasses.

Color Center Formation

Although remarkable progress has been made in the understanding of the mechanism of color center formation in simple crystals, the knowledge on the color center formation in glasses is very scanty. When coloration occurs in glasses that contain neither polyvalent ions nor easily reducible metallic ions, it is only natural that one turns to the color center formation as the possible explanation. This viewpoint is further confirmed through the investigations of Britt[27], Smakula[166], Schulman, Ginther, Klick, Alger and Levy[149], Sheline, Sharp and Arner[156] and others. The fading of color formed upon irradiation of atomic radiations with time (e.g., Monk's work[116]), with heating (e.g., Beilby's work[19] upon many others) and with irradiation of visible light (e.g., Kernohan and McCammon's work[96]) also tends to indicate that the coloration of many glasses is due to the formation of color centers.

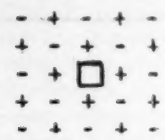
The fundamental investigations on the formation of colors in ionic crystals such as alkali halides by radiations and other means were due to Pohl[132] and his coworkers. De Boer[23], Mott[118], Seitz[150-154] and many other recent investigators have added much to the present understanding and progress of the problem. A comprehensive review of the subject was given by Seitz[152]. It seems advisable to give a brief review on the color center formation in crystals before one is engaged in the more complicated situation concerning glass.

If a transparent alkali halide crystal is irradiated with x-rays, cathode-rays, or other nuclear radiations, or is heated in the vapors of the characteristic metal or halogen, or is subjected to electrolysis, absorption bands in the visible and ultraviolet regions are developed. In other words, coloration results. The main color in the visible region varies with the type of crystal. For chlorides, it varies from yellow for LiCl to blue for CsCl. The absorption maxima for LiCl, NaCl, KCl, RbCl and CsCl are at approximately 3,800, 4,000, 5,500, 6,100 and 6,100 A respectively. The half-widths of the absorption bands are of the order of 1,000 A. These are the main bands which are called the F-band. Actually for each crystal, there is, first, the fundamental absorption band of the alkali halide itself. Then, there are other absorption bands. For example, for KCl, the following bands are known: V-bands (2,200, 3,550 A; after Burstein and Oberley[28] and Casler et al[30]), F-band (5,500 A), R-bands (6,700, 7,200 A), F'-band (7,400 A, very broad), and M-band (8,200 A). With a small addition of $CaCl_2$ to KCl, new bands called Z_1 (5,900 A), Z_2 (6,100 A) and Z_3 have been observed[154]. The introduction of hydride yields the so-called U-band. All these bands can be narrowed by lowering the temperature during irradiation. The boundary of these color bands can be demonstrated to migrate toward the anode when an electric field is applied (e.g., the F-band of KBr at 600°C.). The crystals with these color bands are also photoconducting. These colors can be "bleached" by heating or irradiating with light of characteristic wavelengths. The

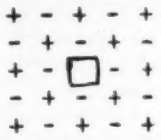
mechanism of formation of these color centers are believed to be as follows:

The radiations produce three effects, two primary ones and one secondary, on a crystal:

(1) Formation of + and — ion vacancies in pairs or group of pairs: These vacancies or imperfections in ionic crystals may be illustrated schematically as follows:

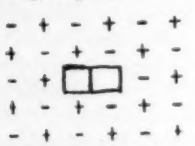


A negative ion-vacancy

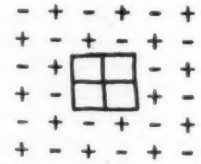


A positive ion-vacancy

These + and — ion vacancies are not mobile. Furthermore, they are unstable and tend to form pairs, quartets, or group of pairs:



A pair of vacancies



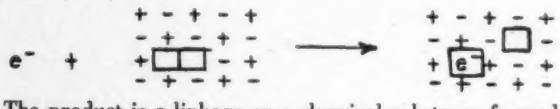
A quartet of vacancies

These pairs or group of pairs of vacancies are very mobile because the movement of pairs of ions across the vacancies is equivalent to the movement of the vacancies themselves in the opposite direction. These vacancy groups or pairs usually migrate from the surface to the interior. The formation of these vacancies has been definitely confirmed by noticing the decrease of density or increase in voids of the crystals after irradiation. Estermann, Leivo and Stern[64] measured the density of KCl before and after strong x-ray irradiation and found that the density was decreased afterward to an amount corresponding to the formation of 10^{18} pairs of vacancies per cm^3 in the crystal, which agrees with data obtained from other sources. The density variation is in the order of 1.4×10^{-4} g/cm^3. This is a very significant experiment and it actually demonstrates without doubt the formation of ion vacancies in crystals during irradiation.

(2) The production of electron-ion pairs due to the primary and secondary effects of radiations as mentioned earlier. Free electrons and positive ions are formed by ionization effects of the radiations. The positive ions are frequently called holes in the sense that holes are atoms deficient of one or more electrons. The free electrons are free to roam, thus able to interact with the ion-vacancy groups which are movable themselves. The holes, or the positive ions, do not move freely in the lattice and only interact with the ion-vacancy groups when the latter migrate to their neighborhood.

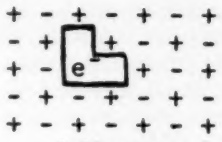
(3) Combination of electrons and holes with the ion-vacancy pairs or groups:

(A) Reaction of a free electron with an ion-vacancy pair:



The product is a linkage or a chemical substance formed by an electron and a negative ion-vacancy and also an unoccupied positive ion-vacancy. The linkage of electron-negative ion-vacancy, like an inverse hydrogen atom, is responsible for the main absorption in the visible region. The color bands are the familiar F-band.

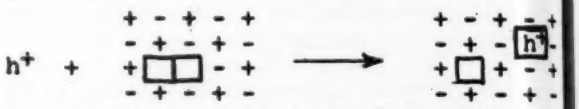
If two electrons, instead of one, occupy the negative ion-vacancy, it produces a F^1-center, instead of the usual F-center, with the absorption bands located at different place. If two F-centers are bound together to form an inverse "H_2-like" molecule, or one F-center is associated with another negative ion-vacancy, these give rise to R-bands. The M-band is formed when a F-center is combined with a pair of ion-vacancies as shown in the following diagram:



A M-center

These centers correspond to those formed by heating the alkali halides in the metallic alkali vapor.

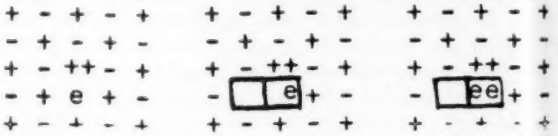
(B) Reaction of a stable hole, h^+, with a mobile ion-vacancy pair:



This is just the reverse of the F-center described above and possibly is responsible for one of the V-centers.

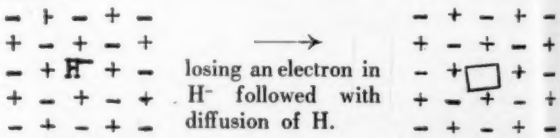
Seitz[152] proposed that the V_2 and V_3 bands observed at room temperatures may arise from the combination of two positive ion-vacancies to which one or two holes are attached respectively. They are analogous to R-centers for electrons.

When impurity ions, such as divalent Ca^{++} ions, are present, additional color centers are formed which are proposed by Seitz[153] to have the following structures:



Z_1-center Z_2-center Z_3-center

These V-centers correspond to the color centers formed when the alkali halide crystals are heated in the halogen vapor. When impurity ions such as H^- are introduced by heating an alkali halide (additively colored in advance—in the atmosphere of hydrogen, a U-center[204, 202] develops, which is associated with the structural arrangement resulting from the displacement of halide ions by H^-. The interesting point of the U-center is that H^-, upon losing an electron, becomes a neutral H which diffuses away easily. A negative ion-vacancy is the result, with the subsequent formation of an F-center upon capturing an electron. The process may be illustrated as follows:



A U-center losing an electron in H^- followed with diffusion of H. A negative ion-vacancy

The combination of electrons and holes with ion-vacancies seems to reach an equilibrium at the concentration of about $10^{19}/cm^3$, where the reversible rate compensates the rate of color center formation, beyond which any further irradiation does not produce additional darkening effect. This saturation effect was observed by various investigators. For example, Forman[68] noted that the saturation is reached for the color center in quartz at an x-ray exposure of about 10^8 r. Kabarkjian[94], for instance, also observed the saturation effect in a microscope slide glass when it is exposed to x-rays. The excitation energy for an F-center is about 3 volts. To ionize it, an energy about 0.1 volt higher than its excitation energy is necessary.

For more complicated crystals, such as quartz, absorption bands at 4,000-4,350 A and perhaps also at $\sim$ 2,050 A have been observed by Smakula[160] and Forman[68]. These bands have not been identified with any structural arrangement of electrons or holes with ion-vacancies. The color in SiO_2-glass was found by Smakula to have absorption bands similar to that in crystalline quartz, namely, 5,400, 3,050, and $\sim$ 2,050 A. The coloration occurred more readily in SiO_2-glass than in quartz, according to Reinhard and Schreiner[138] Recently, many coloration phenomena in quartz were associated experimentally with definite impurities.

So far, there are no direct proofs to show that the colors formed in glasses are due to color centers of similar nature. Perhaps they are of somewhat more complicated structure. However, the parallelism of coloration between crystals and glasses is found quite general. Other phenomena, such as the saturation of coloration on long irradiation, the disappearance of color under illumination of light, long standing, or heating, the thermal luminescence, the photoconductivity and others, were common to both crystals and glasses. Even the formation of color by heat treatment in alkali metal was noticed in glass[5]. It is likely that much of the coloration in glass must be due to the formation of color centers similar to that observed in crystals. For glasses high in alkali content, the interactions are primarily those of electrons or holes with ion-vacancies formed by alkali-ions or oxygen-ions in the glass structure. Because of the complexity of composition and structure of glass, the color centers formed in glass must be more variegated than that in simple alkali halide crystals. Consequently broad absorption bands due to the overlapping of many absorption bands result and the colors generally appear impure. Despite this, relatively simple absorption bands have been observed in simple glasses such as SiO_2, $CaO.P_2O_5$, etc.[116]. In the case of a $CaO.P_2O_5$ glass with a small admixture of boron oxide, Monk found an absorption peak near 4,700 A. Although the half-width of the band is over 2,000 A, it is interesting to see an absorption peak, rather than an over-all gray color, in glass. It is possible that the cherry red color in a $BaO\text{-}P_2O_5$ (40:60) glass observed by Hoffmann[89] may also contain a broad absorption peak. The $K_2O\text{-}BaO\text{-}Al_2O_3\text{-}P_2O_5$ glasses now being studied by Kreidl and associates exhibit purple coloration. It should be advisable to study the color centers in detail of simple glasses, such as that in the systems $R_xO\text{-}P_2O_5$, where R being Li, Na, K, Ca, Sr, Ba, etc. From a study of this nature, one might be able to identify certain absorption peaks associated with a certain structural configuration in glass similar to those in alkali crystals. Sheline, Sharp and Arner[156] found absorption bands of very weak intensity at $<$ 4,000, 5,100 and 6,180 A when a borosilicate glass was irradiated with radon gas. They attributed the colors to the formation of color centers. Britt[27] has made similar sugestions earlier in her study of coloration of glass by x-rays. To further confirm the formation of color centers in glass, it will be interesting to carry out experiments of the kind that has been found successful in the case of crystals. The migration of a colored "edge" in an electric field at an elevated temperature, for example, will be very convincing, if it can be carried out. The coloration of glass by heat treatment in metallic or oxygen vapors at high temperatures should prove interesting. It should also be interesting to study the corresponding U-center formation, if any, in glass. The density change during irradiation, if observed, should serve as a proof of the formation of ion-vacancies. Since the refractive index of a glass, similar to the density, is sensitive to the structural compactness of glass and it can be measured with an unusually high accuracy, it may be interesting to measure the change of refractive index during the irradiation. The decrease in density due to the formation of ion-vacancies near the saturation is of the order of 0.0001 gm/cm^3. It may be estimated, by assuming the constancy of refraction or refractivity of a glass, that the decrease of refractive index would be about 0.00002 unit.

The fading of color after irradiation or the rate of regeneration or recovery was found to be logarithmic with temperature, being high at high temperature, by Kersten and Dwight[97]. Kelmm and Berger[98] found that the rate of generation is proportional to the 4th power of temperature. The mechanism of fading undoubtedly is related to the mobility of the electrons in glass which, in turn, is related to the structure of glass. It is known that glasses containing lead fade rapidly. Monk[117] seems to think that lead containing glass may be colored intensely during irradiation, but fades almost instantaneously when the glass is removed from the irradiation, and suggested the study of coloration at the moment of irradiation by a remote controlled system through a periscopic arrangement. It should also be interesting to observe if the coloration of lead-containing glasses may be obtained or frozen by the application of low temperatures. An interesting point may be noted here in passing. Some organic plastics were found by Monk to resist coloration by radiations about 1000 times better than glasses. Furthermore, the plastics after coloration did not easily fade. This seems to indicate strongly that the coloration in organic plastics is chemical in nature, such as in oxidation or reduction reaction, rather than due to the formation of color centers. This seems to be reasonable from the point of view of structural chemistry. One is also reminded of the recent development of a polyvinyl-chloride dosimeter[203] in which liberation of HCl by γ-rays is detected chemically through the acid sensitive dyes.

Monk indicated that a single component substance, such as pure SiO_2, B_2O_3, diamond, etc., does not color easily by radiation. This is not universally true. For example, the alkali halide crystals discolor relatively easily. In the case of SiO_2, B_2O_3, diamond and the similar materials, Monk's argument is partially true, because the forces involved in the Si-O, B-O, C-C bonds are strong and the formation of vacancy-pairs, which is necessary in the color center formation, is not too easy.

An extension of the reasoning would indicate that a glass with high alkali content should color easily. This seems in agreement with the work of Schmidt[146], who found that a glass with 25-30 per cent Na_2O developed a blue color easily on irradiation. As mentioned earlier, Kreidl, in cooperation with the workers of the Naval Research Laboratory, also noticed that a K-Ba-phosphate glass exhibits a sensitivity to discoloration similar to that of the silver-containing photosensitive dosimeter-glass. Bastress[18] also observed that the reducibility of the silver ions in glass increases with the basicity of glass. It seems evident that the high alkali content in glass contributes to the looseness in glass structure and consequently the ease of the formation of ion-vacancies, which is essential for the creation of color centers. The high alkali content, however, is not desirable from point of view of chemical durability, though it may be protected with a plastic or another glass. This is the reason why a dosimeter composed of a crystalline phase or a glass phase imbedded in an ultraviolet absorbing glass is also proposed here as a practical substitute for a pure glass dosimeter. On the other hand, if the purpose is the prevention of coloration, then the glass should contain the least amount of modifiers. Preferably some lead or titanium may be incorporated as suggested by Long[108], Monk[116], and others. Johnson[93], Rothermel, Sun and Silverman[140], Hood[91] and others[13] seem to find the use of phosphate type of glass advantageous to the prevention of coloration. However, it is important to note that the presence of potassium and barium in a phosphate glass renders the glass sensitive to coloration. It should be interesting to investigate if corresponding borate and silicate glasses are more sensitive to coloration than the phosphate glass or not. The effect of adding fluorides, chlorides, bromides, iodides, sulfides, etc., would also be of interest.

Effect of glass structure: Since the formation of color centers is primarily dependent on the formation of vacancy-pairs of groups in glass, it is natural that in addition to the considerations of bond strengths the role of the submicroscopic structure of the glass is important. The submicroscopic or the sub-x-ray-diffractionic crystalline structure in glass, if present, will constitute imperfections in the glass and may, in many ways, help the formation of ion-vacancies between the boundaries of these crystalline structures and the glass matrices. The fact that the structure of a glass is not as simple as Warren's picture of a "perfectly" random orientation has become more and more evident in recent years. The presence of small crystalline structure with a dimension of several tens or several hundreds atomic diameters have shown to be possible through the work of Debye and Bueche[51] using optical scattering technique, and of Milligan, Levy and Peterson[115] using neutron diffraction technique. Barber and Fajans[17] argued with favorable evidences that there are ring formations, instead of a continuous net-work, in boron-containing glasses. Douglass[55], in his careful study on density of glass, arrives at a similar concept that there is sub-microscopic structure in glass. Bachman[14] has also shown by infrared absorptions that the crystalline structure is somewhat carried over to the glassy state when glasses were melted from crystals of similar compositions. The behavior of borosilicate glass which is rather sensitive to radiations, and yet can be remedied much more effectively by the addition of cerium, might be related to the structure of this sub-microscopic nature. It is known through Debye and Bueche's work that flint glass also has the sub-microscopic structures. The extremely rapid fading effect of lead-containing glass may have escaped one's attention from the nature of color formation in flint glasses.

Perhaps the most convincing and direct evidence that an ordinary silicate glass possesses a sub-microscopic crystalline structure imbedded in a glassy matrix may be found in the recent work of Prebus and Michener[208]. Through the study of electron transmission micrographs of several silicate glasses, these investigators found that these glasses possess inhomogeneities in structure on a scale greater than that postulated by Zachariasen and Warren. "A glass of composition: SiO_2 54.6%, (Al_2O_3 + Fe_2O_3) 14.8%, CaO 17.4%, MgO 4.5%, B_2O_3 8.0% (Na_2O + K_2O) 0.6% possesses sinuous or helical chain structures having width of about 30A and lengths of several hundred A. Fine flame blown fibers of the same glass possess silica chains of greater length and these are aligned with the fiber axis. A glass of the composition: SiO_2 63.6%, Al_2O_3 3.8%, Fe_2O_3 0.2%, CaO 14.0%, MgO 2.6%, B_2O_3 6.7%, Na_2O 8.7%, K_2O 0.4% possesses similar aggregates which tend to form rods in parallel alignment. The second phase of these glasses appears homogeneous and flows readily at fractured surfaces."

Besides the effects of the structure of glass, the presence of electron "sinks" in glass also plays an important role in the prevention of discoloration of glass. When electrons are captured before they are trapped at the negative ion-vacancies, no color centers will be formed. Consequently, coloration is retarded. Multivalent ions such as cerium are very efficient in playing such a role. The following gives a somewhat more detailed discussion on the role of these ions.

Role of Cerium and Other Similar Agents:* It is an established fact that an optical crown glass with, say, 1 or 2 per cent of CeO_2 added in the batch, will remain transparent under irradiation of 10^6 r of γ-rays. The same amount of radiation would have colored the same glass without cerium addition to such a degree that it is completely non-transparent. The works of Montgomery and Scott (on solarization), Eckert[58] (on x-rays), Gier and Smelt[74] (on electrons), Monk[116] (γ-rays and other nuclear radiations), and others[26], have demonstrated beyond doubt that the presence of cerium prevents the formation of color centers in glass. That is probably due to the fact that Ce^{4+} is such a powerful oxidizing agent or electron acceptor, that its presence removes free electrons which would otherwise form color centers with negative-ion vacancies or sites created by radiations in glass. In this connection, it might be interesting to study the effect of iron. The works of Schmidt[145], Badger and Ottoson[15], Ctyroky[46] and others have indicated that iron may be successfully used to prevent the coloration in glass by ultraviolet radiations. Monk found that glasses containing iron fades rapidly. It will be interesting to see if a Ce-containing glass is discolored during irradiation but fades instantaneously as the radiation source is removed. The electrode potential for Ce^{3+} —Ce^{4+} is —1.60 volt in aqueous solution. If the electrode potentials in aqueous mediums are any indication at all for the glass medium, one would also attempt to study other poly-valent ions such as Co^{3+} and Pb^{4+}. The electrode potentials of Co^{2+} —Co^{3+} and Pb^{2+}—Pb^{4+} are—1.82 and—7.75 volts respectively.

(*Continued on page* 614)

GLASS SESSIONS ATTRACT LARGE ATTENDANCE AT SAFETY CONGRESS

Intensive attention to the prevention of accidents in glass plants was well rewarded this past year, a standing-room-only audience was told at the opening session of the National Safety Council's Glass and Ceramics Section in Chicago October 20.

During the year, the group was told by its general chairman, J. C. Dittmar, chemical engineer with National Lead Company, accidents in the flat drawn glass division of the industry were reduced 27 per cent over the previous year's toll. In the tableware division, the reduction was 3 per cent, while in the machine and molded products division a 5 per cent drop was recorded. Six plants which are members of the Section went the entire year, for 4½ million man-hours of operation, without a single lost time accident.

"If they can do it, we all can," Mr. Dittmar declared. He warned, however, that "we cannot rest on our laurels."

Four additional glass companies became members of the Section this past year, Mr. Dittmar stated, in reviewing the group's activities. A number of new engineering data sheets dealing with specific accident prevention techniques were issued or will shortly be published, he said, while still others are contemplated.

Decision was reached to create a new post of vice chairman for ceramics who will deal with that field exclusively hereafter. To meet also the problem of accident prevention in the smaller glass plants which cannot afford a full time safety director, the group decided to add a new "Associations Committee" for liaison work with these smaller firms. In time, Mr. Dittmar explained, it is hoped that through the educational efforts of this committee the small companies will realize the importance of safety and will team up for active participation in the Section's program.

New officers chosen to serve for the coming year are: *General Chairman*—Thomas R. Donoghue, Pittsburgh Plate Glass Company; *Vice Chairman—Glass*—W. G. Hazard, Industrial Hygienist, Owens-Illinois Glass Company; *Vice Chairman—Ceramics*—Harry A. Jackson, Frigidaire Div., General Motors Corp.; *Secretary*—N. P. Ingalls, safety engineer, Norton Company.

Assignments to committee chairmanships, announced by Mr. Donoghue, are as follows: *Membership*—John B. Fullen, Kopp Glass Works; *News Letter*—James L. Morris, Federal Glass Company; *Engineering and Health*—Fred S. Kriger, Corning Glass Works; *Safety Contest*—H. Waugh, Anchor Hocking Glass Corp.; *Safety Promotion*—J. H. Gattrell, Blue Ridge Glass Corp.; *Program*—John P. Stephanson, Ball Bros. Company; *Associations Committee*—C. T. Grimm, Structural Clay Products Institute.

"Grinding Wheel Safety" was the subject of the first of two technical papers presented at this, the sixth annual meeting of the Glass and Ceramics Section. The occasion, also, was the 40th national safety congress of the National Safety Council.

Ralph N. S. Merritt, product safety engineer for the Norton Company, declared that, "If ordinary care and common sense are used, the grinding wheel is not a dangerous tool and grinding is not a hazardous operation." Accompanying his talk he showed a sound and color film produced by his company, which graphically presents the wrong and right ways for handling grinding wheels. He told of the work of the Grinding Wheel Institute, whose members, he said, are unselfishly cooperating on their mutual problem of building maximum safety into their products.

Sixty years ago, Mr. Merritt said, his own company began to study the factors involved in correct mounting and use of grinding wheels. The knowledge developed has been incorporated in a series of booklets, samples of which he distributed at the meeting. It is not generally known, he added, that the American Standards Association has approved a code to guide wheel manufaeturers, the last revision of which was made in 1947.

He took issue with the charge, sometimes heard, that dust from grinding wheels will cause silicosis. This could not be true, he said, of the synthetic wheels now widely used because they are free of materials producing silica dust. In closing, he offered the use of the Norton Company film, just shown, of which he said there are 35 copies available either from Worcester or the branch offices in many cities.

In a detailed survey of "Chemical Hazards in the Glass and Ceramics Industry," Joseph A. Houghton, industrial hygienist with Liberty Mutual Insurance Company, declared that, while many toxic materials are utilized, "no material used cannot be used safely." Arsenic, he pointed out, is a very toxic substance, yet it is used in glassmaking with few and infrequent casualties because workers have learned to respect its destructive potentialities and use it properly.

The greatest chemical hazard in the glass industry, Mr. Houghton said, is exposure to mineral dusts. Recently there has been an increasing trend toward granting awards if dust is found in the worker's lungs, even though the classic symptoms of disease resulting from such dust are lacking. This trend, he said, is evident in all industries, thus making control of dusts of any kind imperative.

Lead poisoning is seldom heard of as it was in the past, he went on, although lead intoxication is prevalent. In the glass industry, control of lead dust is "generally good," he stated. With reasonable care in keeping dust to a minimum, lead can be handled without serious results, he asserted. Even though classic symptoms of lead poisoning are not noticeable, the dust does, however, cause minor disturbances, such as lead colic, and it can affect the worker's abilities and general well being. Its effects should be evaluated on an over-all basis, considering the man's age, the extent of exposure and other factors.

The permissible limit for lead dust which a man can stand without harm, he stated, is now 1.5 milligrams. A few years ago this standard was 5 milligrams but this has been lowered to protect those most susceptible. Control measures should be shaped to prevent or lessen exposure of the individual.

In general, for control of dusty materials, Mr. Houghton suggested automatic materials handling equipment, automatic weighing and batching machines and use of

water to keep the material as moist as possible. Even 2 per cent or 3 per cent of moisture, he said, will help in keeping dust down. A respirator should be used only after all other protective means fail, he advised, and consideration should be given to substitution of less toxic materials for any found to be causing trouble.

All these, he pointed out, are engineering means for dust control. Medical control is also essential and in the large plant the medical service should be extensive. Doctors and nurses, he declared, can at times be more effective than a safety director. Being in intimate contact with the worker who comes to the office, they can notice what he may be doing or not doing that affects him adversely. The man will, for example, pay attention and follow orders from a nurse who instructs him to wash his hands, where he would resent a safety director's orders to do it. The doctor, too, can detect chance clinical signs showing up in an examination and, if advisable, can follow up with subsequent checkups.

Mr. Houghton also suggested that it is well to give attention to fumes from the plant which may be affecting nearby parks, gardens, orchards or even electrical transformers on poles near the plant. He advised a careful engineering survey first to determine the magnitude of any air pollution before action is taken to curb it.

Continuing, Mr. Houghton discussed a number of metallic substances used in varying volume in the glass industry, including berylium, selenium, cadmium, barium compounds, fluorides, lithium, antimony, cobalt, germanium oxide, also contact acids, caustics, nickel salts, etc. Potential hazards of each were explained, so far as present knowledge of them exists, and suggested measures were outlined for reducing and controlling any toxic effects. He also discussed carbon tetrachloride used for cleaning motors, and sometimes, also, for cleaning clothes in the worker's home. This dangerous compound should be kept under lock and key, he advised, to discourage pilfering.

For Tuesday afternoon's final session in the Congress Hotel's Lincoln Room, the Program Committee provided a film on the subject of ventilation and an inspirational feature dealing with safety promotion in general.

W. Z. Hazard, Director, industrial hygiene, Owens-Illinois Glass Company, made use of a colored motion picture produced by American Air Filter Company, in cooperation with the Michigan State Department of Health and the University of Michigan, to present the underlying principles of industrial exhaust systems with particular reference to use of hoods on intakes to increase their efficiency. Supplementing this, Mr. Hazard showed the small model he uses to demonstrate the same basic exhaust principles in his company's plants.

Continuing, he brought up the problem of protection from radiant heat, and referred to a recently developed cotton fabric coated with aluminum which is being offered for protective garments by the Minnesota Mining & Mfg. Company. A representative of this company was introduced to explain the merits of his product, which he did with the help of a short color movie taken during tests of this aluminum coated fabric in comparison with other untreated cloth. His product, he claimed, reflects 90 per cent of all radiant energy.

For the grand climax of this year's conference, Clyde R. Powell, Public Relations Director of Lehigh Safety Shoe Company, was billed for a talk entitled "Don't Bet Your Life." Mr. Powell confessed that he could not add anything new to what has been said over the years about safety. He thought perhaps the folks might like to see some of the parlor magic tricks with which he has been entertaining enlisted men at USO clubs. The audience was agreeable, so Mr. Powell proceeded.

First he began gathering up a pile of clinking coins from unlikely places, like the ears of folks on the front row, or from the window drapes and brightly colored handkerchiefs on a table. Then he chopped up a stout cord and an instant later pulled it out of somewhere in its original one-piece condition. He shuffled and dealt pack after pack of cards, coming up each time with the same card on top. And, finally, he "reluctantly" agreed to demonstrate his hypnotic powers, provided five men would volunteer to cooperate. The five came forward and, of course, were put through some hilarious stunts.

Maybe all that seems a long way removed from the subject of "safety," but thoughtful analysis of the deftly worded running patter with which Mr. Powell accompanied his performance reveals considerable substance whose significant points these sleight-of-hand tricks served to emphasize.

In effect, he put over these thoughts: "We're playing the game of life for keeps. We don't get a second chance. One instant of thoughtlessness or inattention can be fatal. Safety has to be sold. It can be sold by reiterating its principles over and over, as the hypnotist does with his subject, until they become so deeply engraved on the subconscious mind that they automatically act to protect us in the moment of danger."

It was a decidedly new and different way of preaching safety and it is quite certain that no one who saw and heard this unusual but effective "lecture" will ever forget its lessons.

Many of the safety specialists from the glass industry found opportunity during the five-day Chicago meeting to attend some of the scores of other sessions devoted to the infinitely varied aspects of industrial safety promotion. Among the speakers at a conference on industrial nursing was a noted glass industry figure, Dr. C. F. Shook, Medical Director of Owens-Illinois Glass Company.

"Our problem is people," Dr. Shook asserted in his talk. "Our opportunity is people. Our profession is people. A good health and safety program, in other words, is not a cold, inanimate plan on paper. It is a live, active project, involving thinking, planning and acting—not of machines, but of people. We are in industrial medicine because we like people and we recognize a fertile field for the advancement of health and safety."

He emphasized the need for teamwork in his advice to the nurses to strive toward "building a working team of people who are interested, not only in their company and work, but their own health and safety as well."

"While maximum efficiency and machine-like precision in production is the American way of doing things," he said, "certainly this does not hold true in medicine. Sometimes," he explained, "what the injured or ill employee needs most is a friendly smile, a kind and sympathetic word and a helping hand."

For visitors to the 40th National Safety Congress, a special effort was made to assemble the largest display of safety equipment probably ever brought together in

(*Continued on page* 614)

OPTICAL SOCIETY OF AMERICA ANNUAL MEETING

This meeting had a rich and varied program of 85 papers, including 22 invited speakers ranging in subject all the way from nuclear physics (Francis Bitter, "Looking into the Nucleus") to flying saucers (Donald H. Menzel, "The Optical Theory of Flying Saucers"). With regard to the latter paper, those of us with romantic imaginations, busily concocting theories involving men from Mars, were disillusioned to hear Dr. Menzel's prosaic explanation based on classical optical phenomena. The meeting opened with Norbert Wiener's invited paper on "Optics and the Nature of Spectra" followed by Peter Elias's "Optics and Communications Theory," carrying us to that intriguing and exotic field of theoretical physics in which optics, electronics and the Bell system are soul mates. It is refreshing to note that the fraternity of scientists can still produce a Norbert Wiener, who knows not the boundaries of specialization within which so many of us revolve.

There were 25 papers in the field of spectroscopy, 6 of which formed an invited symposium. Particularly interesting were Richard Tousey's discussion of firing spectrographic equipment in V-2 rockets for the purpose of studying the upper atmosphere, and E. M. Purcell's review of the techniques and accomplishments of radio astronomy in line spectra work. Dean George Harrison's invited paper on an echelle spectrograph, plus several contributed papers concerned with echelles, indicated that this new dispersing element is beginning to carve a niche for itself in the field of spectrographic instrumentation.

An invited paper by H. K. Hartline of Johns Hopkins discussed the physiological basis of vision, and three papers from the H. R. Blackwell group at the University of Michigan treated spherical aberration in the retinal image and detection and contrast threshold in the fovea. Other papers in this session reported on studies of ocular tremor and dark adaptation, and particularly impressive were a series of transparencies of fundus photographs taken with an Ektachrome film in a Zeiss Nordensen retinal camera shown by Kenneth Ogle of the Mayo Foundation.

Of special interest to glass technologists was a paper by W. F. Koehler describing investigations of the polishing process by multiple beam interference techniques. Irregularities as small as 20A in height on a polished surface seem to indicate that glass does not flow during polishing. Quantitative results showed close agreement with Thompson's planing theory of polishing. R. J. Spindler and W. S. Rodney of National Bureau of Standards reported on a comparitive study of the refractive index from 0.347 to 3.5 microns of domestic and European (Hereaus) fused quartz in which they found the European samples lower in index several points in the fourth place. Small differences in dispersion were also detected. Another paper on refractive index measurement was that of J. B. Saunders and T. R. Young of N.B.S. describing a new interferometer for the measurement of index gradients in glass discs up to 5 inches thick, a refined requirement in large photographic lenses of high quality.

The omniscience of the science of colorimetry was indicated in a session on Saturday at which Munsell standards for bronze paints and artists oil colorants shared the session with permanent glass standards for maple syrups and honey. In a paper presented by H. R. Davidson and E. Friede, an interesting report was made on 12,000 individual judgments of the color match acceptability of 300 samples. Samples termed acceptable in 50% of the observations fell within ellipsoids having radius vectors 2½ times those of the corresponding Mac Adam ellipse in the chromaticity plan and about 0.15 Munsell value units parallel to the Y axis

Two invited papers dealt with the use of calculating machines in optics (James G. Baker, "The Use of Automatic Calculating Machines on Problems of Optical Design" and H. R. Grosch "High Speed Arithmetic: The Digital Computer as a Research Tool"). On this same subject, one of the many interesting tours arranged by the local committee of the Optical Society included a trip through the Harvard Computing Laboratory where the Mark I and Mark IV Harvard digital computors are in operation. The Mark IV is now being used extensively for optical ray tracing and a study is underway to devise a means by which the machine will carry through the complete design of a lens from a list of specifications without the benefit of human assistance.

In a session on geometrical optics an automatic process for generating high aperture paraboloids with little or no hand retouching required was described by H. E. Lewis, H. T. Betz, N. W. Rodelius and M. Wolfson. At this same session, F. G. Back of the Zoomar Corporation presented data on a new telescope with a range of area magnification of 100 to 1 over an apparent field angle of 53%.

At the dinner meeting, President Brian O'Brien bestowed the Adolph Lomb Medal for 1952 on Dr. Aden B. Meinel of Yerkes Observatory for his accomplishments in the field of astrophysics and optical design. The Frederic Ives Medal for 1952 was presented to Dr. Ira S. Bowen, Director of Mt. Wilson and Palomar Observatories, in recognition of an outstanding career as an astronomer, an optical physicist and a scientific administrator. On the following morning, Dr. Bowen presented an address entitled "Optical Problems at the Palomar Observatory" in which he described some of the complex instrumentation in use at the observatory. Dr. Harlow Shapley, Director of the Harvard College Observatory, was speaker of the evening at the dinner, choosing as his subject "Cosmography and Such." After a short review of the 1952 highlights in astronomy, Dr. Shapley concentrated his attention on the "and Such" with an ample display of his lively wit, including fascinating conjectures on the world-wide distribution of argon atoms exhaled by Cleopatra when she sighed amorously at her first meeting with Mark Antony.

• The Salesmen's Association of the American Chemical Industry held a chemical sales clinic at the Commodore Hotel in New York City on October 28. Edward A. Bush, of the Bush Aromatics Division of the Dow Chemical Company, is president.

• C. Cialdella and C. Montione, Chemical Research Laboratory of Bausch & Lomb Optical Company, have left their positions to undertake graduate studies at Cleveland, Ohio.

BOOK REVIEW

Physico-chemical Properties of the Ternary System of Sodium Oxide, Lead Oxide and Silica

A Russian book under the above title recently reached this country. It represents the final report on the exhaustive experimental study of the system Na_2O-PbO-SiO_2 carried out between 1928 and 1947 under the general guidance of Academician I. V. Grebenschikov. Fifteen scientists took part in the investigation, and their account is 220 pages long.

The system sodium oxide-lead oxide-silica was selected as it combines industrial importance with a relatively low melting range, easily accessible to experimentation.

The first chapter of the book discusses the equilibrium diagram of the system. Only the part containing 50 molecular % or less of sodium oxide was investigated. In this region six crystalline compounds can form. They are: (1) $Na_2O.2PbO.4SiO_2$, orthorhombic needles having perfect cleavage, melting at 630°C. and having refractive indices 1.744 and 1.782; (2) $Na_2O.3PbO.6SiO_2$, tetragonal prisms (no cleavage) melting at 717°; refractive indices 1.704 and 1.707; (3) $Na_2O.3PbO.6SiO_2$, orthorhombic bipyramids (moderate cleavage), stable below 540° and transforming at this temperature into the preceding compound; (4) $Na_2O.2PbO.3SiO_2$, monoclinic, perfect cleavage, melts at 615°; refractive indices 1.691 and 1.790; (5) $Na_2O.3PbO.7SiO_2$, hexagonal, moderate cleavage, melts at 725°, refractive indices 1.726 and 1.750; (6) $3Na_2O.3PbO.11SiO_2$, composition uncertain, monoclinic plates, perfect cleavage, melts at 645°, refractive indices 1.617 and 1.681.

In the same region seven ternary eutectic points were found. Their temperatures, compositions and the solid phases present are indicated in Table I. The numbers in parentheses refer to the above crystalline compounds.

Table I. Ternary Eutectics in Na_2O-PbO-SiO_2 System.

	Temperature °C.	Composition Na_2O PbO SiO_2 molecular percents			Solid phases present
(a)	670	4.5	35.0	60.5	SiO_2, $PbSiO_3$, (2)
(b)	580	13.5	35.0	51.5	$PbSiO_3$, (1), (2)
(c)	575	19.0	30.0	51.0	Na_2SiO_3, $Na_2Si_2O_5$, (4)
(d)	570	16.5	29.5	54.0	$Na_2Si_2O_5$, (1), (4)
(e)	610	17.0	22.5	60.5	(1), (2), (6)
(f)	570	17.0	38.0	45.0	$PbSiO_3$, Na_2SiO_3, (4)
(g)	580	10.0	62.5	27.5	Pb_2SiO_4, Pb_3SiO_5, Na_2SiO_3

The ease of crystallization greatly depends on the composition of the melt. When crystallization is difficult, the glass is less subject to devitrification. The compositions thus favorable to glass formation are concentrated near the eutectic points (a), (d) and (e), near compound (6) and also at the molecular composition Na_2O 16, PbO 18, SiO_2 66%.

The second chapter brings extensive material on the viscosity of sodium-lead glasses between 540°C. and 1460°C. It was found, e.g., that the minima of viscosity, observed by Preston in 1939 and attributed to the presence of compounds $Na_2Si_2O_5$ and $Na_2Si_3O_7$ in the molten state, do not exist.

In the third chapter viscosity measurements in the softening range are reported.

Electrical conductivity of molten glasses is the subject of the fourth chapter. As a rule, conductivity is higher the higher the percentage of Na_2O in the melt. Substitution of lead oxide for sodium oxide lowers the conductivity in a simple way, but substitution of silica for sodium oxide has a complex effect. The effect of change of composition on electric resistance often is quite different from its effect on viscosity.

Fifth chapter deals with electric conductivity, both surface and volume, of solid glasses at 30-70°C. One of the results may be mentioned. Compound (1) above reveals itself by a maxium on the curve "surface conductance versus composition."

Optical properties and densities of 66 glasses are reported in Chapter 6. If the data are plotted as lines of equal refractive indices in the triangular diagram whose corners represent Na_2SiO_3, SiO_2 and $PbSiO_3$, these lines appear almost as parts of concentric circles round the $PbSiO_3$ point. However, compounds (1) and (5) above can be discerned on this diagram.

In Chapter 7 measurements are recorded of the "sintering temperature" defined as the temperature at which the Newton rings between two polished plates start to disappear because of "welding." This temperature was 200° to 300°C. lower than the liquidus temperature of the glass. When glasses are slowly heated, up to five thermal effects can be observed on the curves of temperature against time. The largest endothermal effect is caused by molecular transformations, and the largest exothermal effect is due to crystallization of silicates. They are described in Chapter 8. Chapter 9 summarizes X-ray patterns of sodium silicate glasses.

Chapter 10 deals with the dielectric losses at high frequencies. These losses increase with temperature and have a minimum at some glass composition, e.g., near the composition of the crystalline phase (1) above.

Raman spectra are discussed in Chapters 11 and 12.

In Chapters 13 and 14 the heats of dissolution in 40% HF are compared for crystalline silicates and glasses of the same composition, the glasses being used in both quenched and annealed state. From these measurements the heats of glass formation and of quenching can be calculated. For instance, transformation of $PbSiO_3$ from crystalline into glassy state is accompanied by absorption of 5.9 cal. per gram-molecule.

In Chapter 15 changes are described which heating and subsequent rapid cooling cause in the refractive index of glasses. These changes reveal the known transformations of tridymite and crystobalite.

Measurements of the refractive index of glasses between room temperature and softening range (about 500°C.) are found in Chapter 16. From the room temperature to about 400-460°C., the refractive index varies but little, and the direction of the change depends on composition. Thus, the index of sodium silicates decreases, and the index of lead silicates increases on increasing the temperature. However, above 400-460°C. the refractive index rapidly decreases when temperature increases for all the glasses examined.

The final chapter points out that some of the compounds listed above can be detected also by measurements on liquid glasses, e.g. by viscosity measurements.

Inventions and Inventors

Annealing and Tempering

Tempering Bottles. Fig. 1. Patent No. 2,613,480. Filed September 23, 1942. Issued October 14, 1952. One sheet of drawings. Assigned to Emhart Manufacturing Company by Charles E. Mongan, Jr.

Improved strength of bottles or other hollow ware is accomplished by surface-treatment of such ware immediately after removal from a forming machine.

The device as indicated in Fig. 1 shows a means of heating a rotating bottle 11 by means of heating nozzle 10 within the container and an external tubular nozzle 55 outside the container. The above nozzles are provided with combustible gases for heating or a flow of air for chilling. This is accomplished by means of the various connecting valves 46, 48, 61 and 62. When the glass of the bottle wall has been heated to its tempering temperature, the combustible gases are shut off and proper flow of air is substituted through the same nozzles. When the desired degree of chilling is accomplished the flow of air is reduced for further cooling.

The patent contains two claims and 15 references were cited by the Patent Office.

Opalized Glass. Fig. 2. Patent No. 2,610,444. Filed July 7, 1949. Issued Sept. 16, 1952. One sheet of drawings. Fredrik Wilhelm Anton Kurz, Nybro, Sweden, inventor.

Fig. 2. Opalized Glass.

A method is described for forming and producing an opalized effect on the surface of glass articles used primarily for lighting fixtures.

The production of the glass body is indicated in Fig. 2, where the primary formation is made in an open mold 1. While the glass body 14 is in the mold, a suitable design 15 may be pressed or formed on the upper surface of the glass. After the designs are formed, the glass body is removed from mold 1 and reheated. The formed glass body in the plastic heated condition is transferred onto a curved mold (not shown) so as to accurately follow the shape of the curved mold, but without affecting the designs on the opposite sides of the glass body. The result is a glass fixture which actually hides the source of light, but at the same time imparts high luster and brilliance to the glass article.

A consideration of all the drawings is necessary to fully understand the objects of the invention.

The patent contains 11 claims and references cited were: 709,796, Ripley, Sept. 23, 1902; 720,138, Hartung, Feb. 10, 1903; 1,146,910, Wiley et al., July 20, 1915; 1,571,139, Nolen, Jan. 26, 1926; 1,670,110, Fraser, May 15, 1928; 2,218,654, Paddock, Oct. 22, 1940; and 2,352,957, Kell, July 4, 1944.

Stabilizing Molecular Arrangement of Glass Thermometers. Fig. 3. Patent No. 2,610,445. Filed April 14, 1951. Issued Sept. 16, 1952. Three sheets of drawings. Assigned to Taylor Instrument Co. by Lawrence C. Liberatore.

Heat treatment of glass articles, especially thermometers, is effected by apparatus shown in Fig. 3. Such treatment is said to stabilize the molecular arrangement

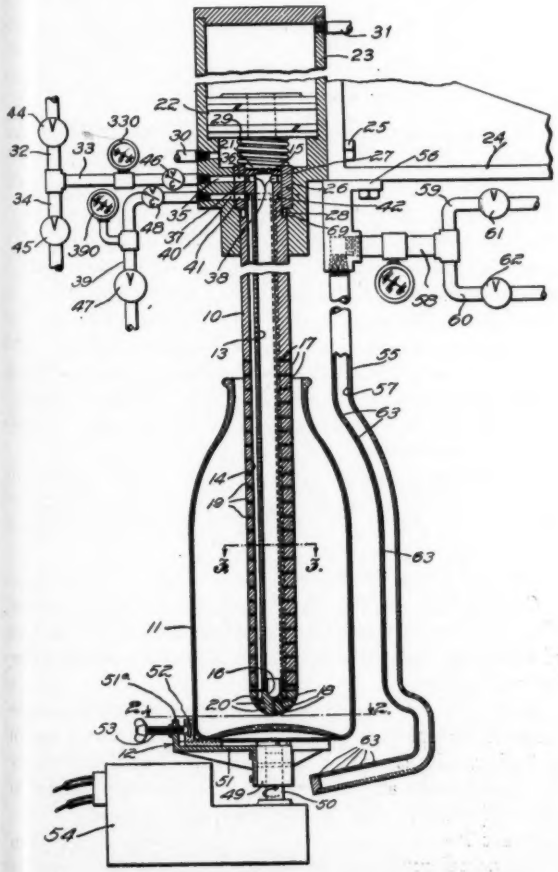


Fig. 1. Tempering Bottles.

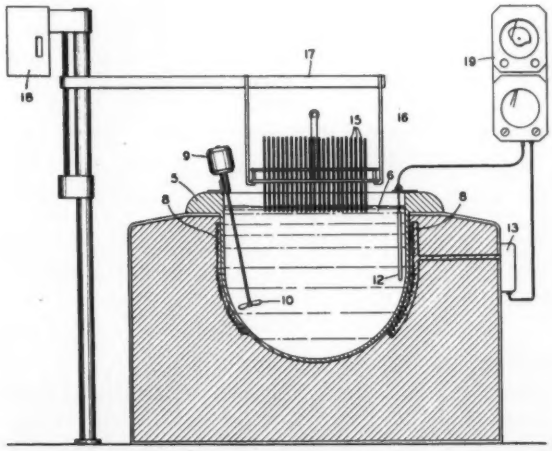


Fig. 3. Glass Thermometers.

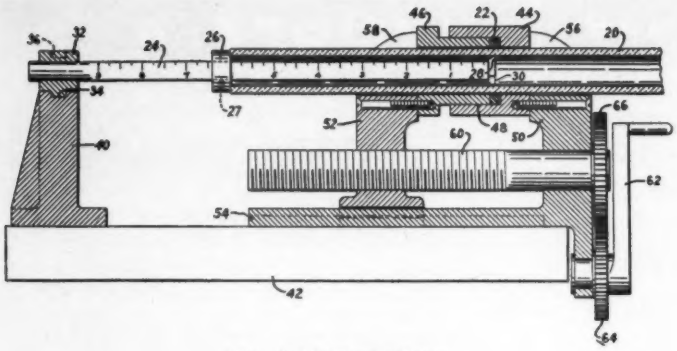


Fig. 4. Cutting Tubing.

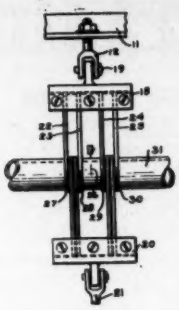


Fig. 5. Glass Cutter.

of the glass article so that subsequent warpage does not take place.

The open-topped tank 5, made of nickel, contains an inert molten liquid 6. Liquids suitable for use in the bath are sodium nitrate, potassium nitrate, or mixtures of the two. The unfilled thermometers 15 to be filled are placed in rack 16. The temperature of the bath is controlled by means of rheostat 13 which governs flow of current to heating elements 8. Uniformity of temperature is maintained by motor-driven agitator 9.

Many glass articles, such as thermometers, are made of two or more different types of glass, such as lead glass B for stem and normal glass C for the bulb. The types of glass which are suitable, such as borosilicate glass A, lead glass B and normal glass C, have compositions and characteristics indicated in the following table:

Glass	A	B	C
SiO_2	81.0	61.9	68.8
B_2O_3	13.0	0.2	2.3
Al_2O_3	1.7	1.9	1.5
Na_2O	4.4	10.9	14.7
CaO	..	..	5.7
PbO	..	24.0	..
ZnO	..	..	7.0

Glass	Softening Temperature, Degrees F.	Annealing Temperature, Degrees F.	Strain Temperature, Degrees F.	Expansion $\times 10^{-7}$
A	1,500.8	1,041.8	962.6	32
B	1,189.4	845.6	786.2	87
C	1,295.6	1,000.4	933.8	89

Heat treatment is then applied over a desired time-temperature schedule (not shown) desirable for each type of glass.

The patent contains 11 claims and the references cited were: 2,148,630, Lillie et al., Feb. 28, 1939 and 479,631, Great Britain.

Glass Compositions

Spherical Glass Beads. Patent No. 2,610,922. Filed March 14, 1950. Issued Sept. 16, 1952. No drawings. Assigned to Minnesota Mining and Manufacturing Co. by Warren R. Beck.

The use of highly-reflecting glass beads in a paint for highway center-lines and cross-walks has made such markings highly visible to the night-time motorist and has contributed materially to the safety of night driving.

Glass beads with high index of refraction (1.65–1.70) and a reflex-reflection of 1.7 candlepower (per foot-candle per square foot) are highly desirable.

The desirable combination of properties has been obtained in the following approximate limits of composition:

SiO_2	15–35
Al_2O_3	8–25
TiO_2	8–25
MgO	2–15
CaO	8–24
B_2O_3	0–15
Na_2O	0–10
F_2	0–5

The following raw-batch compositions have proven desirable:

	1	*2*	*3*
Silica	26.0	26.0	26.0
Aluminum hydrate	24.7	24.7	24.7
Raw dolomite	—	—	43.0
Calcined dolomite	—	22.5	—
Soda ash	7.9	7.9	7.9
Fluorspar	2.8	2.8	2.8
Titania	15.0	15.0	15.0
Boric acid	12.9	12.9	12.9
Magnesia	14.8	4.0	4.0
Calcium carbonate	23.2	—	—

The patent contains three claims and the following reference was cited: 2,517,459, Armistead, Aug. 1, 1950.

Tube and Cane Machines

Cutting Tubing. Fig. 4. Patent No. 2,612,001. Filed May 12, 1950. Issued September 30, 1952. Two sheets of drawings. Assigned to General Motors Corporation by Orlan Denlinger.

A machine for cutting brittle tubing is described. The machine is especially adapted to cut very short lengths of tubing, with smooth breaks that are substantially perpendicular to the axis of the tubing. The method is simple, safe and reliable, and at the same time tool and labor costs are low.

The actual cutting of the tubing is illustrated in Fig. 4. The cutting is accomplished by bringing the jaws 50 and

52 of the vise together to squeeze the rubber-like member 22 until the tubing 20 is cut exactly at the center line of the rubber-like member 22. The latter member is squeezed sufficiently to completely fill the recess between the telescoping members 44 and 46 and press firmly against the outer surfaces of tubing 20. Better control of the cut is accomplished by scoring the inside of the tubing with a rod 24 which is provided with a sharp Carboloy tool 28. Exact lengths of the tubing may be cut with the aid of rod 24 which is provided with a marked scale.

The patent contains six claims and the references cited were: 999,668, Montaperto, Aug. 1, 1911; 1,922,426, Fahrney, Aug. 15, 1933; 2,116,129, Stringer, May 3, 1938; 2,157,067, Brown et al., May 2, 1939; and 2,442,495, Hull et al., June 1, 1948.

Glass Cutter. Fig. 5. Patent No. 2,607,169. Filed March 22, 1948. Issued Aug. 19, 1952. One sheet of drawings. Assigned to Corning Glass Works, Corning, N. Y., by Robert B. Randels.

A tube-severing device is described which operates very rapidly and at the same time provides sufficient accuracy that subsequent trimming is not necessary.

A lever provided with a weight is adjustable to tighten loops 27-30 about tube 31 to provide the desired degree of local circumferential compressive force to sever the tube 31. An abrasive knife is provided to score the tube at the position 26. The design provides breakage along the tubing where the maximum axial tension is introduced by the compressive equipment. This condition is highly desirable for precision breakage.

The patent contains nine claims and references cited were: 999,668, Montaperto, Aug. 1, 1911; 1,892,814, Stahle, Jan. 3, 1933; 1,922,426, Fahrney, Aug. 15, 1933; 2,157,067, Brown et al., May 2, 1939; 2,174,183, Shaw, Sept., 26, 1939; and 2,219,698, Owen, Oct. 29, 1940.

Reshaping Glass Tubing. Patent No. 2,613,479. Filed April 21, 1947. Issued October 14, 1952. One sheet of drawings, none reproduced. Assigned to Corning Glass Works by Guy E. Stong.

An ingenious method is described for producing tubing of accurate bore and internal dimensions by reshaping during heating. The glass shapes may be either circular or non-circular in cross-section. Previously prepared tubes are threaded over a suitable mandrel and drawn through a heating furnace by a single driven roller. As the tube reached its softening temperature, reshaping is effected by simultaneous drawing of the tube and the forming action of the mandrel. Precise accuracy can be maintained and a single tube six feet in length may contain enough glass to produce sixty feet of precision bore tubing.

The patent contains six claims and the references cited were: 972,166, De Bay, Oct. 11, 1910; 339,503, Germany, July 21, 1921; and 547,880, Great Britain, Sept. 16, 1942.

Miscellaneous Processes

Vitreous Enamels for Aluminum. Patent No. 2,608,490. Filed Aug. 1, 1950. Issued Aug. 26, 1952. No drawings reproduced. Assigned to Foote Mineral Company by John W. Donahey.

Aluminum and aluminum alloys have offered considerable difficulty in enameling because of their high coefficient of expansion, low melting point, and strong reducing action.

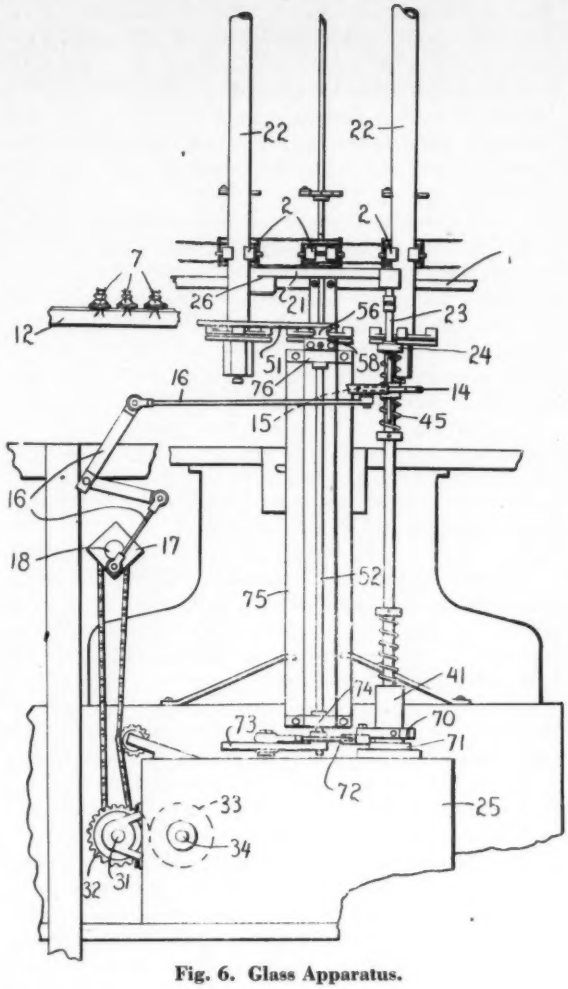


Fig. 6. Glass Apparatus.

A wide variety of lead-free frits were prepared and examples of the various compositions are presented in Table I. The proportions of the various oxides are given as percent by weight.

Table I

Example	III	IV	V	VI	VII	VIII	IX	X	XI
Li_2O ..	3.6	3.5	2.7	3.3	3.4	2.9	2.7	2.9	2.96
Na_2O ..	13.5	13.1	10.9	14.2	14.9	11.9	11.3	11.9	7.67
NaF ..	8.2	7.8	7.4	8.1	8.5	8.1	7.7	8.1	14.56
Al_2O_3 ..	20.7	19.9	18.7	20.6	21.5	20.4	19.4	20.4	21.03
B_2O_3 ..	7.0	6.8	6.4	7.0	11.8	6.9	6.6	7.0	2.00
P_2O_5 ..	43.1	41.5	46.9	42.9	35.9	42.6	40.6	42.6	43.91
CuO ..	3.9	3.7	7.0	3.9	4.0	...	...	...	7.87
CoO ..	...	...	...	...	...	7.2	...	...	...
CdO ..	...	...	...	...	...	...	11.7	...	...
NiO ..	...	...	...	...	...	...	...	7.1	...
TiO_2 ..	...	3.7	...	...	...	...	...	...	...

The patent contains 12 claims and the references cited were 2,436,825, Prior, Mar. 2, 1948 and 30,168, Austria, 1906.

Glass Apparatus. Fig. 6. Patent No. 2,605,590. Filed

June 30, 1949. Issued Aug. 5, 1952. Four sheets of drawings. Assigned to Sylvania Electric Products, Inc., by Charles A. Young and Harold E. Baker.

An automatic mechanism for feeding electric lamp mounts to sealing position upon a circular type sealing machine. The machine, which is used for sealing tubular lamps, has a turret 1 provided with a plurality of sealing heads 2.

The mechanism of the invention transfers a mount 7 which it picks from a supply of mounts, and places it in sealing position upon a sealing head 2. Lamp mounts are fed to the work axis at a time in the work cycle when no lamp tube is present. The lamp tube and mount are sealed in the conventional manner.

The drawings disclose many novel mechanisms for control and protection of filament. The complete operations can be learned only by a study of the patent.

The patent contains three claims and references cited were: 734,734, McBerty, July 28, 1903; 1,593,825, Higgins, July 27, 1926; 1,813,565, Conn, July 7, 1931; and 1,947,610, McNamara, Feb. 20, 1934.

Smoothing Corundum Surface by Heat. Fig. 7. Patent No. 2,608,031. Filed April 16, 1946. Issued Aug. 26, 1952. Two sheets of drawings, assigned to Union Carbide and Carbon Corporation by Malcolm H. Barnes and Edward L. McCandless.

This is an unusual invention which provides a novel means of rapidly and inexpensively treating crystalline corundum bodies by heat to give them a smooth surface free from pits and scratches. The surface finish may thus be accurately controlled and the quality of synthetic corundum rods can be greatly improved.

The process as seen in Fig. 5 can be best accomplished by the use of a multi-jet flame burner. One end of the tube is sealed 15 and the opposite end comprises a shank 17 connected with a suitable source of combustible gas, such as oxy-natural gas mixture. Three spaced gas discharge ports 19, 21 and 23 are drilled radially through the inside wall of the arc 13 in such a way that the flame jets 20, 22 and 24 will intersect one another approximately at the center of curvature of the arc. Such a flame spreads transversely and heats a considerable portion of the rod 18.

Temperatures in excess of 1900°C. are needed for successful glossing. Heat-glossed synthetic corundum rods are said to be free from scratches and pits when examined with an electron microscope at a magnification of 2500X.

The patent contains two claims and references cited were: 1,680,681, Herzog, Aug. 14, 1928; 1,852,840, Fuwa et al., Apr. 5, 1932; 2,011,872, Rava, Aug. 20, 1935; 2,018,056, Delpech, Oct 22, 1935; 2,371,486, Walker, Mar. 13, 1945; 2,405,892, Lederer et al., Aug. 13, 1946; and 243,251, Great Britain, Nov. 26, 1925.

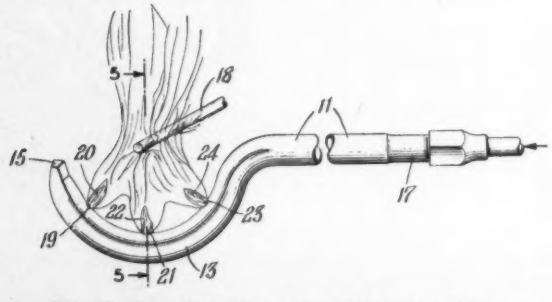


Fig. 7. Smoothing Corundum Surface by Heat.

Ultraviolet-Transmitting Glass. No. 2,612,726. Filed April 21, 1950. Issued October 7, 1952. No drawings. Assigned Corning Glass Works by Martin E. Nordberg.

This patent is a continuation of Patent No. 2,106,744, 2,221,709 and 2,505,001 and extends the use of such glasses for ultraviolet-emitting lamp envelops. Glass articles containing over 94% SiO_2 are produced by melting and forming easily meltable glasses of lower silica content and extracting the soluble non-siliceous constituents with acid leaving a highly porous glass. This glass is then consolidated to a vitreous non-porous condition by heating.

The improved procedure as applied to tubes is to first eliminate water loosely held in the pores by heating to 600-900°C. The dehydrated tubes are then heated in the anhydrous atmosphere to 950-1050°C. to reduce any ferric iron to the less absorptive ferrous state. Such heating also eliminates any residual water and gas from the glass before consolidation of the pores. Complete consolidation of the pores is effected by heating to 1150-1250°C. The atmosphere within the furnace may best be controlled by the use of carbon monoxide at substantially atmospheric pressure and warping or flattening of the tubes is presented by rotation during heating.

The patent contains eight claims and the references cited were: 2,106,744, Hood, Feb. 1, 1938; 2,279,168, Kalischer et al., Apr. 7, 1942; 2,303,756, Nordberg et al., Dec. 1, 1942; and 2,505,001, Nordberg, Apr. 25, 1950.

Ultraviolet-Transmitting Glass. No. 2,612,727. Filed April 21, 1950. Issued October 7, 1952. No drawings. Assigned to Corning Glass Works by Martin E. Nordberg.

This patent is a continuation of Patent No. 2,612,726 and offers an improved procedure for making tubes of high-silica glass. Initial dehydration of the tube is accomplished by heating at about 600-900°C., after which they are heated in a reducing atmosphere containing hydrogen for a sufficient time to reduce any ferric iron that may be present. This temperature may vary from 900° to 1050°C. Complete consolidation of the porous glass is then obtained by heating in the range between 1150°-1250°C. An anhydrous atmosphere is desirable during the latter heating in order that water may not be formed. Such gases as nitrogen, carbon dioxide, carbon monoxide, sulfur dioxide, helium, neon and argon are usable. The practice as described eliminates the difficulties encountered in vacuum-firing as given in Patent No. 2,505,001.

The patent contains nine claims and the references cited were: 2,106,744, Hood, Feb. 1, 1938; 2,279,168, Kalischer et al., Apr. 7, 1942; 2,303,756, Nordberg et al., Dec. 1, 1942; and 2,505,001, Nordberg, Apr. 25, 1950.

• The Westinghouse Electric Corporation will expand its manufacturing operations in the Boston area with a $1,250,000 building project at its Sturtevant Division plant in Hyde Park, Mass. The Hyde Park plant manufactures air conditioning equipment, commercial fans and blowers.

Research Digest

Study of Silica Brick From a Glass Tank Crown

The constant effort for greater efficiency from continuous glass melting tank furnaces is a challenge to the refractories industry for higher quality materials of construction. A higher rate of glass melting is the principal source of increased efficiency, but a large amount of the potential gain is lost if the furnace's calendar life excessively shortened by the resulting higher melting temperatures and greater attack on the refractories by batch ingredients in the furnace gases.

When a major weakness in construction of a tank furnace is corrected by use of improved material or design, the weakness is often shifted to some other portion of the furnace. This results in a continuous program of finding and strengthening those portions which appear to threaten success in achieving more efficiency in the subsequent campaign.

In some furnaces, the melting zone section of tank crowns has eroded under these conditions and so has become a point of weakness. Other crown sections have been a source of some ware defects in the form of drips from fluxing action in the brick joints.

Chrzan, Petrie and Swain (*Journal of the American Ceramic Society*, July 1952), have made a study of silica brick which had been used in actual glass melting tanks in order to learn the mechanism of attack and thereby suggest types of improvement that would be required to lengthen crown life and reduce the formation of stones and cords resulting from corrosion.

For this study, samples were taken from three locations in a window glass tank, the first from the center of the crown in the zone of greatest erosion in the melting section between ports Nos. 1 and 2 of a 5-port tank, the second from the center of the crown of the refining section and the third from the center of the crown in the cooling section just ahead of the drawing machine. The tank was side-fired with natural gas in the typical regenerative system. It had a neck, but no curtain wall between the melting and refining sections. The area of the entire melting section to the neck was about 1500 sq. ft.

Each of the sample brick was in service for more than 3½ years, during which time more than one hundred thousand tons of glass were produced. The brick were cooled down and reheated once during this period. It is estimated that the specimens in the center of the crown of the melting section were subjected to an average temperature of about 2750°F. on the hot fact throughout the operating period. Chemical analyses, petrographic analyses, X-ray studies and physical property measurements were made on the various samples.

From the data obtained, it was concluded that (1) in the melting section of a soda-lime window glass tank melting a salt cake batch, the silica brick in the crown absorbed significant amounts of sodium oxide to lower the refractoriness and to result in moderate slagging. The cause for deep penetration of the soda was not found.

(2) Only a moderate depth of penetration of sodium oxide occurred in the refining and cooling sections of the tank although the hot, altered zone contained more soda than the corresponding zone in the brick from the melting section. This higher amount may be due to the lower vapor pressure of soda in this soda-silica glass at the lower temperature of service.

(3) There was a moderate concentration of alumina and lime in intermediate zones of all brick, apparently caused by the drawing of glass from the hottest zone by capillary action.

(4) There were traces of SO_3 in the hot faces of all brick, but none of absorption of lime or other fluxes as dust from the batch materials.

(5) The attack on silica brick in intermediate zones back in the crown was estimated to occur in the temperature range from 1300° to 1500°F. and a tentative explanation of the mechanism of attack is as follows: (a) sodium chloride and sodium sulphate, present in the furnace gases as vapor, condensed out in open joints, (b) the eutectic between these chemicals melted and attacked the silica to form a glass, (c) chlorine, sulphur dioxide, and later sodium oxide were vaporized as the glass was formed and as it flowed slowly down the joint to zones of higher temperature, (d) the glass did not dissolve more silica in its passage because it lost soda from the surface faster than it could pick up silica from underlying layers of glass, and (e) it finally became so refractory through loss of alkali that it formed stalactites capable of resisting the full temperature of the gases of the section. Attack at intermediate zones of brick in the crown of the melting section did not occur apparently because of the relative absence of sodium chloride. It is suggested that the use of the relatively new superduty silica mortars in laying brick in the crown would reduce or prevent this type of attack.

(6) In the hot face of the brick from the melting section, cristobalite was present in large crystals as the predominant phase; the rest of the brick was largely tridymite. The calculated temperature gradient through the brick did not place the portion heated to 2680°F., the accepted inversion temperature between these phases of silica, at the same place as that set up by petrographic and X-ray determinations. It appears likely that the presence of clear glass in the hot sections made the brick somewhat transparent to radiation from the flame so that this zone was heated above the temperatures that would be expected from conduction alone.

(7) The hot faces of the brick from the refining and cooling sections showed large crystals of tridymite present as the predominant phases. Since these brick were heated to an average temperature of 2300° and 2000°F. or less, respectively, this finding conformed to the accepted phase relations.

(8) The cooler sections of the brick and unused silica brick of the same brand but of later manufacture were shown by careful petrographic study, confirmed by X-ray diffraction data, to consist largely of tridymite.

• The Westinghouse Lamp Division has announced a price increase of approximately five per cent on almost all of its fluorescent lamps.

HOUZE NAMES DIRECTOR OF RESEARCH

Dr. Robert H. Peckham, Associate Professor of Research Ophthalmology, Temple University School of Medicine, has been named Director of Research of the L. J. Houze Convex Glass Company, it has been announced by E. V. Ogg, Executive Vice-President.

Dr. Peckham, widely recognized in the optical field for his extensive studies of sun glare and sunglasses, was formerly secretary of the Army-Navy Vision Committee during World War II when research was first undertaken to solve the problems of loss of night vision among troops in the field.

Author of 22 published scientific papers on visual acuity, color perception and dark adaptation, Dr. Peckham first attracted the attention of the optical profession during the last war when as a Commander of the Navy, he was assigned as officer in charge of Visual Research for the Bureau of Medicine and Surgery, Washington, D. C., directing the application of research, the findings of which resulted in the first conclusive proof that sunglasses were a necessity to prevent loss of visual acuity at night.

Graduate of the University of Rochester, Dr. Peckham was at one time associated with his father, the late Ray Clifford Morse-Peckham, in the manufacture of optical instruments in Waterbury, Conn. He was also on the staffs of Bausch & Lomb Optical Company and the Polaroid Corporation and received his Ph.D. from Johns Hopkins University. Dr. Peckham joined the Department of Ophthalmology at Temple University in 1934 and became an Associate Professor in 1946. He is a member of the Optical Society of America and the Southern Society of Philosophy and Psychology and holds a patent for a safelight system for photographic development, granted in 1945.

DAVID H. GOODWILLIE DIES AT AGE OF 65

David H. Goodwillie, 65, who had retired last April as Executive Vice President of Libbey-Owens-Ford Glass Company, died at his home on October 17 of a cerebral hemorrhage. He had not felt well during the day and was unable to attend a meeting that morning of L-O-F executives.

At the time of his death Mr. Goodwillie was serving as a Director of Libbey-Owens-Ford, Toledo Edison Company and Commerce National Bank. He was also a consultant on glass problems for L-O-F Glass.

Mr. Goodwillie was born in Oak Park, Ill., on January 15, 1887. He was graduated from the Oak Park high school in 1904 and received a degree in mechanical engineering from Cornell University in 1908.

In November 1909, he arrived in Toledo as a young engineer of 22 to take charge of the city's new water filtration plant. Two years later, he was named superintendent of the entire waterworks system. He resigned this post in 1914 to go into private engineering work, but was named city service director two years later. Mr. Goodwillie's work in the public service field attracted the attention of officials of the Edward Ford Plate Glass Company. In 1920, Mr. Goodwillie was named works engineer at the Rossford plant.

He was chief engineer at Rossford when the Bicheroux pot casting method of making plate glass was put in use in 1926. The 750-foot continuous grinding and polishing lines were installed three years later. When the Ford company merged with the Libbey-Owens Glass Company in 1930, Mr. Goodwillie was named Vice President and a Director of the new Libbey-Owens-Ford Glass Company. Initially he was responsible for the direction of the Engineering and Research Departments but later was given the added responsibility for production. He was made Executive Vice President in April 1933, a post he held until his retirement last April.

During the 22 years of Mr. Goodwillie's association with Libbey-Owens-Ford, the most modern methods of making plate and window glass have been installed in its plants and he played an active and important role in the company's progress. Mr. Goodwillie was widely known throughout the American and European glass industries and last fall he made his 11th trip to Europe to visit glass factories there to add European developments in glass technology to the improvements originated in the L-O-F research and engineering departments.

But, in the years of his service to the glass industry, Mr. Goodwillie did not neglect his civic responsibilities. He served for 10 years as a member of Toledo's Street Railway Board of Control; was a member of the Board of Education from 1928 through 1933 and its president in 1932 and 1933 and was elected to the Toledo City Institute of Medical Research and served on a state committee in 1948 studying Ohio's schools for blind and deaf children. He was an Ohio delegate to the Republican national conventions in 1936 and 1952.

Survivors include his wife, Gladys; sons, David B., of Toledo; John H., manager of the L-O-F Shreveport plant; and Robert B., of Charleston, W. Va.

D. E. SHARP TO RECEIVE HONORARY DEGREE

Donald E. Sharp, Assistant Director of Research in charge of Glass Technology at Libbey-Owens-Ford Glass Company and internationally known in his field of glass science, will receive the honorary degree of Doctor of Science at Lafayette College, Easton, Pa.

Joining L-O-F in 1943 in his present position, Mr. Sharp has had much to do with the advancement in glass-making techniques in the last decade. He was born in Corning, New York, and his first work was as an assistant in the physical laboratories of the Corning Glass Works. He attended the University of Wisconsin and the Carnegie Institute of Technology, serving for a time as assistant in the Physics Department at Wisconsin. In 1942 he was awarded an honorary professional degree in Ceramic Engineering by Alfred University.

Mr. Sharp has published more than 25 technical articles on glass and several patents have been issued in his name in the fields of glass composition, reflection and signal devices and glass forming machinery.

Current Statistical Position of Glass

Employment and payrolls: During August 1952, employment in the glass industry rose to reach a preliminary 124,600. Compared with the previous month's adjusted employment figure of 122,600, an increase of 1.6 per cent is shown. Employment during August 1951 was 124,400, which is .1 per cent less than for August this year.

Payrolls during August also rose and were reported at a preliminary $37,633,357. This is a 6.9 per cent rise over July payrolls of $35,196,417. During August 1951, payrolls were $33,449,087, which is 12.5 per cent less than for August this year.

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Shipments of glass containers during September 1952 also dropped and were 9,888,669 gross. Compared with the August record shipments of 11,310,056 gross, a drop of 12.5 per cent is represented. Shipments during September 1951 were 9,632,719 gross, or 2.6 per cent less than for September 1951. At the close of the first nine months of 1952, shipments of glass containers have reached a total of 87,107,579 gross. This figure indicates that 1952 shipments are running 3 per cent behind the 89,855,426 gross total shipped at the end of the corresponding period in 1951.

Stocks on hand at the end of September 1952 were 9,594,477 gross. This is 1.5 per cent higher than the 9,449,115 gross on hand at the end of August and 2.4 per cent less than the 9,838,855 gross on hand at the end of September 1951.

Automatic tumbler production during September 1952 dropped considerably to reach 3,816,452 dozens. Compared with the preceding month's production of 5,832,795 dozens, a drop of 34.5 per cent is represented. Production during September 1951 was 4,655,807 dozens. Shipments during September were also off from August and were reported to be 4,050,124 dozens. This is 21.8 per cent below the 5,181,290 dozens shipped during August. During September 1951 shipments were 4,387,355 dozens. Stocks on hand at the end of September were 8,389,443 dozens. This is 2.7 per cent below stocks of 8,627,981 dozens on hand at the end of August. Stocks on hand at the end of September 1951 were 12,556,474 dozens.

Table, Kitchen and Household Glassware: Manufacturers' sales of machine-made table, kitchen and household glassware during August 1952 were 3,353,538 dozens. This is 13.8 per cent above the 2,944,891 dozens sold during July. During August 1951 sales were 3,506,491 dozens. At the close of the 12-month period ending August 1952, manufacturers had sold a total of 38,801,317 dozens. This is 4.3 per cent less than the 40,563,756 dozens sold at the end of the corresponding period in 1951.

During September 1952, manufacturers' sales of machine-made table, kitchen and household glassware dropped 1.3 per cent to reach 3,308,373 dozens. This is a drop from the 3,353,538 sold during August. Sales during September 1951 were 2,891,961 dozens. At the end of the 12-month period ending September 1952, manufacturers' sales have reached a total of 39,217,729 dozens. This is 2.1 per cent less than the 40,099,903 dozens sold at the end of the same period in 1951.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

	September, 1952
Narrow Neck Containers	
Foods	1,463,856
Medicinal & Health Supplies	1,132,928
Chemicals, Household & Industrial	630,372
Beverages, Returnable	434,232
Beverages, Non-returnable	41,395
Beer, Returnable	80,587
Beer, Non-returnable	686,953
Liquors	711,549
Wines	323,429
Toiletries & Cosmetics	558,267
Sub-total (Narrow)	6,063,568
Wide Mouth Containers	
Foods	*2,575,032
Dairy Products	326,752
Medicinal & Health Supplies	318,667
Chemicals, Household & Industrial	141,523
Toiletries & Cosmetics	101,504
Packers' Tumblers	161,014
Sub-total (Wide)	3,624,492
Total Domestic	9,688,060
Export Shipments	200,609
TOTAL SHIPMENTS	9,888,669

*This figure includes Home Canning.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production September 1952	Stocks September 1952
Foods; Medicinal & Health Supplies; Chemicals, Household & Industrial; Toiletries & Cosmetics	Narrow Neck	3,594,532	3,448,400
	Wide Mouth	*3,283,502	*3,072,013
Dairy Products		346,819	286,676
Beverages, Returnable		563,585	699,502
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Beer, Returnable		139,176	242,742
Beer, Non-returnable		750,522	633,109
Liquors		830,148	725,213
Wines		363,048	280,066
Packers' Tumblers		172,363	141,037
TOTAL		10,100,435	9,594,477

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New Equipment and Supplies

SEALING-IN ATTACHMENT

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The sealing-in attachment, marked "S" on the accompanying photograph, is made in many different types and styles. The device marked "S" consists of a sealing head for television tubes. The attachment is made to handle television tubes from 2″ in diameter up to practically any size. It is made to fit practically any kind of head without removing the main drive of the device. All holders are interchangeable and can be placed into the head "S" whenever such operation is desired. The crossfire can be moved up and down by hand or fixed in position as required. Crossfires would be arranged for gas, air, and oxygen or oxygen and hydrogen. Burner manifolds are also removable and adaptable for the various operations.

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Mine Safety Appliances Company has announced all-leather heat-resistant gloves said to be able to "take" temperatures up to 800°F.

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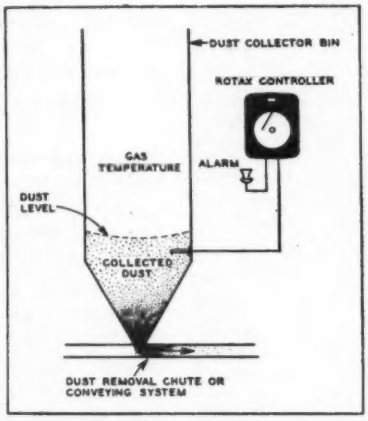
By means of a pivoted, swinging frame, internal parts are accessible from the front of the case for easy removal without special tools. The unit, in addition to measuring a single flow, can be provided with two flow elements so that the gas and air flow records can be combined and coordinated for efficient combustion. The measuring element is the Hays differential type diaphragm unit which will accommodate static pressures up to ten pounds and differential pressures up to 20″ water.



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Instrumentation Data Sheet, 1.4-1a, presents basic control instrumentation information for the regulation of forehearth temperature. Included in this four-page data sheet are complete instrument specifications for both thermocouple and radiomatic type installations on both low pressure and high pressure type glass feeders.

Instrumentation Data Sheet, 11.0-5a, describes the application and operation of instrumentation as used with test chambers produced by Tenney Engineering, Inc., Newark, N. J. This 4-page data sheet discusses the various temperature, pressure and humidity control problems involved in various types of test chambers as designed for various uses. Several different control systems are schematically illustrated.

Bulletin 5601 covers a new multi-purpose screw type thermocouple head. It can be used for single or duplex thermocouple or resistance thermometer terminal blocks and is protected against freeze-up and rust. Dimensional details and terminal blocks available are given in the bulletin.

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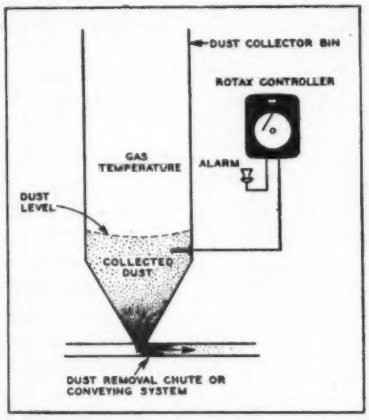

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Minneapolis-Honeywell Regulator Company, Brown Instruments Division, Wayne and Windrim Aves., Philadelphia 44, Pa., has available four new pieces of literature covering the company's products.

Bulletin 9603 contains data on combustion safeguard systems for industrial ovens, furnaces and other heat treating applications fired by multiple oil or gas burners. The bulletin describes system components, lists light-off options available and includes dimensional and operational data.

Instrumentation Data Sheet, 1.4-1a, presents basic control instrumentation information for the regulation of forehearth temperature. Included in this four-page data sheet are complete instrument specifications for both thermocouple and radiomatic type installations on both low pressure and high pressure type glass feeders.

Instrumentation Data Sheet, 11.0-5a, describes the application and operation of instrumentation as used with test chambers produced by Tenney Engineering, Inc., Newark, N. J. This 4-page data sheet discusses the various temperature, pressure and humidity control problems involved in various types of test chambers as designed for various uses. Several different control systems are schematically illustrated.

Bulletin 5601 covers a new multi-purpose screw type thermocouple head. It can be used for single or duplex thermocouple or resistance thermometer terminal blocks and is protected against freeze-up and rust. Dimensional details and terminal blocks available are given in the bulletin.

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OWENS-ILLINOIS PURCHASES POSSIBLE CONTAINER PLANT SITE

The Owens-Illinois Glass Company has acquired approximately 70 acres of land in the Parkrose Area of Portland, Oregon, as a possible new glass container plant site.

C. G. Bensinger, General Manager of the company's Pacific Coast Division, said, "Owens-Illinois has surveyed numerous sites trying to locate property close to the center of the growing Pacific Northwest market."

The Portland site has access to rail and highway transportation, providing effective service to all marketing and producing areas in the states of Washington and Oregon.

ELECTROLUMINESCENCE EXPLORED FOR WESTINGHOUSE

Electroluminescence, the illumination exhibited by a phosphor-coated flat glass panel when subjected to an electromagnetic field, is being explored for the Westinghouse Lamp Division by two top scientists in the field. Professor Georges Destriau and Dr. Joseph Mattler, both from the Sorbonne, University of Paris, France, have been working in the Lamp Division research laboratories for the past nine months on advanced electroluminescence experiments.

The two scientists began exploring the phenomenon in 1935, and have published joint papers on the basic ideas in 1936. In this country, they have been testing a new superior phosphor.

A. C. S. SECTION MEETINGS

The first meeting of the Philadelphia Section of the American Ceramic Society for the 1952-53 season was held recently and Dr. Rudy Sussman of the Management Training Division of The Pennsylvania State College was speaker for the evening. The next meeting has Dr. S. D. Stookey scheduled to speak. He will discuss photographing directly on glass.

"Society Night" will be featured at the December meeting of the Pittsburgh Section. Edward Cramer, President of the Society, will present a talk on "The Organization of the American Ceramic Society." Also expected to attend is Charles S. Pearce, General Secretary, who will relate some of the recent activities of the Society's Board of Trustees. The latter part of the evening will be devoted to a question-and-answer period.

The Trenton Section of the A.C.S. held its first Fall Meeting at which Lt. Comdr. D. Van Gordon, now on leave from the Metal and Thermit Corporation, gave a talk, "The Tile Industry of Japan." R. T. Drennan, of the Kaiser Aluminum & Chemical Sales, Inc., presented a colored sound movie entitled, "Bricks from the Sea," which was of particular appeal to members of the Section because of their broad interest in refractories.

• C. R. Fay, Comptroller of the Pittsburgh Plate Glass Company, was elected a Director of the Controllers Institute at the 21st Annual Meeting of that organization. Mr. Fay, who joined the Institute in 1945, has been Chairman of its Society Security Committee for the past year. He was President of the Pittsburgh Control for 1950-51.

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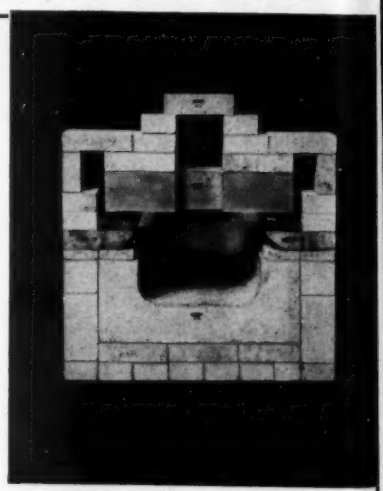

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HOUZE SIGNS NEW UNION AGREEMENT

A ten cents an hour increase will be paid to all hourly employees of the L. J. Houze Convex Glass Company under a new 12-month agreement reached with the three locals of the American Flint Glass Workers Union. Some four hundred employees are covered by the agreement which is retroactive to September 1.

Under the agreement, the union locals pledged to promote efficiency to help the company meet competitive conditions. It did not provide for any material change in working conditions.

GLASSWARE DEFINITION BOOKLET PUBLISHED

A booklet designed to give both consumer and advertiser a clearer conception of glassware terms and definitions has been prepared by the National Better Business Bureau in cooperation with the American Glassware Association.

Allan E. Backman, NBBB Editor and Vice President, described the booklet as a "guide to accurate and informative advertising of glassware" and said that it was developed to promote better mutual understanding of glassware terms by advertiser and consumer.

H. L. Dillingham, Secretary of the American Glassware Association, said the glassware industry heartily endorsed the Bureau's efforts to promote honest and accurate statements in advertising copy.

Reprinted from the Bureau's "Do's and Don'ts in Advertising Copy," the booklet describes the various types of glassware such as lime glass, lead glass and borosilicate glass. Terms such as cut glass, pressed glass, blown glass, opal glass and crystal are clearly defined. Processes which produce decorative effects, such as etching, embossing, sand carving and engraving, are explained.

The booklet definitely recommends against advertising or representing glassware as "rock crystal glassware" since rock crystal, a form of clear, colorless quartz, is not used commercially in modern glassware. It also recommends that the actual capacity of thick-bottomed tumblers be accurately stated in advertising.

"Glassware Definitions" is available, upon request, from the National Better Business Bureau, Chrysler Building, New York 17, N. Y.

AMERICAN POTASH ACQUIRES CHEMICAL COMPANY

American Potash & Chemical Corporation has acquired Eston Chemicals, Inc., Los Angeles chemical manufacturer, it has been announced.

Acquisition of the Eston Company, which becomes a division of American Potash & Chemical Corporation, was accomplished by issuance of 22,837 shares of the latter's Class B stock in exchange for all of the outstanding capital stock of Eston. The Eston Company manufactures agricultural chemicals, including insecticides and fumigants and also produces refrigerants, aerosols and industrial chemicals.

The Eston manufacturing facilities are located at Vernon, California, and the company also has a unit at Torrance which produces ethylene dibromide. The company will be operated as the Easton Chemicals Division.

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GLASS CONFERENCE PROGRAM

Papers to be presented before the Thirteenth Conference on Glass Problems, scheduled for December 4 and 5 at Ohio State University, have been arranged for by Hugh Kline, Corhart Refractories Company, and Dr. Henry H. Blau, Director of the Conference.

The papers to be presented include: "Some Aspects of Controlling the Color of Glasses," Axel Ottoson and C. J. Uhrmann, Imperial Glass Company; "Factors Influencing the Control of Color in Amber Glasses," R. W. Hopkins and W. H. Manring, The Calumite Company; "The Use and Conservation of Selenium in Glass Manufacturing," R. R. Shively, B. F. Drakenfeld & Company, Inc.; "Plant Layout and Design," Roy S. Arrandale, Thatcher Glass Manufacturing Company; "Factors Influencing Plant Design for the Production of Glass Containers," Morton Cressy, Hartford-Empire Company; "The Design, Construction and Operation of Oil Burners for Glass Melting," Thomas Coyle, Maryland Glass Corporation; "End Port Tank Design and Operation," Fred Motsch, Foster-Forbes Glass Company; "Causes and Prevention of Stones," Dr. Howard R. Swift, Libbey-Owens-Ford Glass Company; and "Three Dimensional Furnace Photography," Lester W. Piper, General Electric Co.

The Chairmen for the several sessions of the Conference are Hugh Kline; Marshall Gleason, Gleason-Tiebout Glass Company; C. J. Phillips, Dunbar Glass Company; and A. R. Wishart, Westinghouse Electric Corporation.

OVERMYER FOURTH IRON CLINIC

After the welcoming speech of Max Hawkins, Sales Manager of Overmyer Mould Company, Winchester, Indiana, visiting glassmen settled down to the serious discussion of developments in glass mold metallurgy at the Fourth Iron Clinic recently held by the company.

An interesting paper was presented by Newt Davis, metallurgist at the Overmyer foundry, a paper on a new type of iron perfected locally under the trade name of OMNOD. In this discussion, Mr. Davis was assisted by Harry Kessler, foundry advisor of Sorbo-Mat Process Engineers of New York City.

There followed a discussion, led by Chester P. Overmyer, Sr., President of Overmyer Mould Company, on proper care, repair and cleaning of mold equipment. It was revealed that with proper care, one customer produced 55,000 gross of bottles from one set of mold equipment. This was followed by an hour's tour of the foundry in North Winchester, a luncheon and golf tournament.

Attending the Iron Clinic were glassmen from all over the country. The visitors were luncheon and dinner guests of Overmyer Mould Company, feature of the night being an address by H. C. Herger, President of the Pierce Glass Company and President of the Glass Container Manufacturers Institute. Mr. Herger used as his subject, "The Economic Status of the Glass Container Industry."

Mr. Herger said that the glass container volume follows very closely the dollar volume of disposable income and warned if, as forecast, industrial production starts to decline next year, the result will be less employment and wages and less disposable income for the purchase of civilian goods.

"Whether such decline sets in next year or the year after," he continued, "will depend largely on government expenditures but it does seem, barring the expansion of the war, that such decline is due and will probably continue through at least two or three years.

"Considering the possibility of a mild recession in business starting one or two years hence, certainly we should all be thinking and planning on means for cushioning the effect of such a decline on our individual companies and our industry.

"Another point which should be borne in mind is the fact that even a minor recession is much more difficult to weather under present conditions than ever before."

"MEASUREMENT OF SURFACE TENSION of GLASSES" — ERRATA

The discussion in the next to the last paragraph on page 454, THE GLASS INDUSTRY, September 1952, beginning "Strong adhesion. . . .," is in error by a factor of two. Because $W_{Co} = 2\gamma_\lambda$, the balance of this paragraph, starting with the second sentence, should read as follows.— When $W_{Ad} = 2\gamma_\lambda$ or when Θ is just equal to 0°, the adhesive forces between the solid and liquid are equal to the cohesive forces acting within the liquid. Thus, when the contact angle is greater than 0°, it is theoretically possible to remove the liquid completely from the solid surface.

Equation (9), page 455, should read

$$\gamma = W/2\Pi r$$

in order to be in the form used by Tammann and Rabe[10] and Keppeler[12]. However, James Bailey, Plax Corporation, has brought to the writers' attention an article (J. Soc. Glass Tech., (Trans.), 22, 38 (1938)) in which he points out that the formula as used by the authors cited neglects the hydrostatic pressure exerted on the glass by the surface tension. Such a correction results in the form

$$\gamma = W/\Pi r.$$

This formula, if used by Keppeler, would have resulted in surface tension values in good agreement with other methods.

L-O-F RESEARCH PROJECTS

Six major projects dealing with fundamental research in glass, including some preparing for the oncoming application of atomic force to industry, are now being supported by Libbey-Owens-Ford Glass Company, it has been announced by John D. Biggers, President.

Outstanding among the special projects is one dealing with fundamental glass studies related to nuclear physics and atomic energy in connection with the Phoenix Project at the University of Michigan. The company is also sponsoring three special projects at Battelle Memorial Institute. One of these deals with a study of fundamental principles of glass grinding, another the oxidation potential of molten glass and a third covers fundamental studies relating to metals and ceramic bodies. At Armour Research Foundation in Chicago, there is a project to study the physical and chemical properties of solids, including glass and films on glass.

• Frank Christenson of Refractories & Insulation Corporation was elected President and Chairman of the Board of the Industrial Mineral Fiber Institute, formerly the Industrial Mineral Wool Institute, at its eleventh annual meeting.

This glassmaker checked Allmul performance by conducting side-by-side tests of this B&W electric-fused mullite brick and a semi-mullite brick. Allmul areas in the walls, floors and arches of four hot ports were still in excellent condition after more than a year. The result was a five carload order.

Here are some other reports

"How good is Allmul for burner blocks in hot ports? Our checks showed it gives four to seven times longer life than the firebrick previously used. We've ordered fifty Allmul burner blocks to date."

"After a year in port necks and uptakes, B&W Allmul's appearance was far superior to that of semi-mullite refractories. We are re-ordering Allmul in carload quantities."

Why not test B&W Allmul Firebrick for yourself? You, too, may profit from Allmul's extra-long service life which gives you longer campaigns. Most important, this durable, electric-fused mullite firebrick offers a remarkable economic advantage: it costs approximately as much as semi-mullite brick . . . yet equals the performance of other electric-fused mullite refractories costing substantially more.

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DUST IS SUBJECT OF ARTICLE IN SAFETY BULLETIN

In an article published in the newsletter of the Glass and Ceramics Section of the National Safety Council, R. W. Love, Engineer of the Lamp Division of General Electric Company, stated: As part of a general program to reduce dust hazards which occur during the periodic repair of glass melting furnaces in the Lamp Division of the General Electric Company, particular attention was given to the masonry saws, which have been the major source of the fine silica dust particles recognized as damaging to the health of individuals exposed.

The standard exhaust hoods previously used on these saws did not provide an air velocity at the saw blade sufficient to remove dust particles thrown by the saw, and dust counts taken in the breathing zone of the operator, using either the dry or the wet saws, were found to be above the safe limit.

In order to get a high velocity air movement at the saw blade without requiring an excessive air volume, the saws were modified to accommodate dust hoods built directly into the saw frames. Pans were provided to close the openings under the movable tables, and pans with felted edges were added to the saw arbor to complete the top enclosure. In the adaptation of the "Clipper" saws, the exhaust connection was made adjustable, so that it can follow the adjustable arbor pivot-shaft to the high or low position notches as required.

The saw duty is largely on standard brick sizes, but occasional cuts must be made in large refractory blocks. The side panels of the hood are hinged and may be swung out to accommodate the larger pieces. Every effort was made in this hood design to avoid any reduction in the utility of the saw and also to avoid restricting the normal hand movements or freedom of the operator.

Air velocities measured at various points at the hood opening ranged from 800 to 1,100 feet per minute (fpm.), depending on the degree to which the arbor was tilted in cutting through the brick. Design velocity is 800 fpm. for 2½ square feet of opening or 2,000 cubic feet per minute (cfm.) of air per saw.

The velocity of air under the saw table was about 900 fpm. This velocity is very effective in entraining dust particles carried around the saw and discharged downwards between the operator and the movable table. This carry-over is believed to be the chief source of dust which formerly entered the breathing zone of the saw operator. A neoprene-coated, spiral-reinforced, flexible exhaust hose is used to connect the saw hoods to the exhaust duct. This allows necessary vertical movement of the exhaust connection of the "Clipper" saws.

The dust collectors used are of the cloth bag type equipped with mechanical shakers. Units to take one saw are 5 HP. "packaged" cabinet type, rated to handle 2,500 cfm, at 6" static pressure, and have manually operated shakers. The unit to take two saws is 10 HP, rated 4,000 cfm, at 7" S.P. and is equipped with a power shaker.

In all installations, the collectors are placed outside of the buildings and the discharge stacks are carried high enough to prevent re-entry of the exhaust air into the working area.

Throughout the repair period at the Pitney Works, strong efforts were made to reduce dust arising from all phases of the operation. The surface of the old furnace structure was vacuumed and then wetted with garden hose sprays before and during dismantling. The aisles and working areas were periodically vacuumed or sprayed to reduce secondary dust.

The top courses of pallet loads of new refractories were vacuumed or sprayed prior to use, and the clean-up squads took over during the masons' lunch period and shift changes to clean debris from scaffolds and working areas.

A series of nine air samples taken with a MSA Impinger during the dismantling period using the standard light field method of counting showed dust counts as follows:

Max. 980,000 particles/cu. ft.
(Total of all sizes and types of dust)
Min. 360,000 particles/cu. ft.
(Total of all sizes and types of dust)
Ave. 550,000 particles/cu. ft.
(Total of all sizes and types of dust)

A series of nine air samples taken at the chin level of the saw operators during the rebuild period showed the following counts:

Max. 1,300,000 particles/cu. ft.
(Total of all sizes and types of dust)
Min. 720,000 particles/cu. ft.
(Total of all sizes and types of dust)
Ave. 900,000 particles/cu. ft.
(Total of all sizes and types of dust)

Considering that about 80 men were working in a very congested area and that several carloads of material were handled daily, it is felt that the above dust counts indicate gratifying results of the dust control program.

CARBORUNDUM APPOINTMENTS

The Carborundum Company has announced the election of Harry C. Martin, Director of Research and Development, as Vice President.

A graduate of the University of Toronto, where he obtained his Bachelor of Arts and Master's Degree in chemistry and mineralogy, Mr. Martin joined Carborundum's research laboratory in 1913. About a year later he was placed in charge of the company's silicon foundry operations. He later served in the Coated Products Division and was responsible for the development of a method for making cold molded resin bonded abrasive wheels. Mr. Martin was appointed assistant technical director in 1944 and promoted to Technical Director three years later.

LYNCH APPOINTMENT

Bernard J. Echlin has been appointed Industrial Relations Manager of Lynch Corporation, according to F. K. Zimmerman, the company's president. Mr. Echlin's duties will include labor relations for the five plants of the firm.

A native of Chicago, Mr. Echlin attended De Paul University College of Commerce, receiving a diploma in management, and the De Paul University College of Law, where he received his LLB degree. Mr. Echlin has been employed by the Pullman Company for the past fifteen years, thirteen of which he has worked in the Industrial Relations Department of that organization.

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APPLIED OVER PEMCO *Satin-Etch*

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Safe and easy to apply, Pemco Satin-Etch forms a soft, smooth tone of any desired translucency. Dust will not cling to it. Satin-Etch won't discolor from contact with sulfide-treated cartons.

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Satin-pastels and Satin-white are available in both high and low-firing members. Designs in Pemco Glass Colors may be easily applied over Satin-Etch to make your line a **stand-out!**

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Distinction and Durability
in your glassware decorations

GLASS COLORS for every decorating need are available from Du Pont. Made under exacting scientific control and thoroughly pretested before shipment, these colors provide outstanding highlights for your labels and decorations . . . insure maximum durability under all service conditions . . . bring new economy to your decorating program. Here's why:

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DU PONT TECHNICAL MEN will be happy to help you adapt these colors to your decorating needs. These men will bring a broad background of experience to bear on your individual problems . . . will offer specific recommendations on how you can increase production and cut cost by getting maximum efficiency from the material and equipment used in your process.

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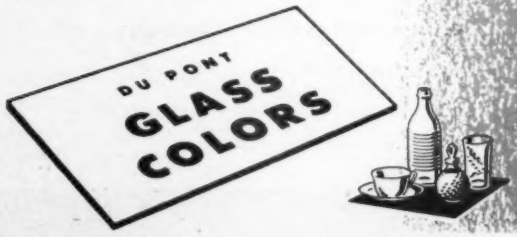

COLORATION OF GLASS . . .

(*Continued from page* 594)

A somewhat puzzling effect of cerium, however, is its role as a color "sensitizer" in photosensitive glass which seems to take advantage of the reducing nature of Ce^{3+}. Among all the photosensitive glasses developed by Stookey and his associates at the Corning Glass Works, it was found necessary to use about 0.05 per cent of cerium oxide as the optical sensitizer. It is possible that the ions Cu^{+}, Ag^{+}, Au^{+}, etc., that Stookey used have higher affinity for electrons in glass than Ce^{4+}; that they will even receive electrons from Ce^{3+}. A similar finding on the coloration by solarization due to the presence of a small amount of cerium (0.005 per cent) by Eckert and Schmidt[59] was observed. These authors also reported the reduction of solarization by using higher concentration (2.6 per cent) of cerium oxide. One of the present writers (N. J. Kreidl) has also noted that a small addition of As_2O_3 with cerium affects the coloration considerably. In the study of the thermoluminescence (*see below*) of a zinc borate glass activated with 0.2% Mn, Cohn and Harkins[200] found that addition of Ce up to about 0.05% increases the thermoluminescence while further addition decreases the effect. The resemblance in the behaviors of Ce is rather interesting. The role of cerium and other similar agents is certainly worthy of further investigations. In addition to the energetic relationship involved in the transferring of electrons, the kinetics on the rate or ease of the electron transferring must be an important factor.

(*To Be Continued*)

SAFETY CONGRESS . . .

(*Continued from page* 596)

one place. The huge show filled the Conrad Hilton Hotel's vast exhibition hall and spilled over into corridors on two floors and even into one of the hotel's coffee shops.

Protective clothing on display ranged from gas masks to goggles and gloves. Shown, too, were safety ladders and scaffolds, as were non-skid floor materials, fire fighting equipment, electronic warning devices, sanitary drinking fountains, group wash-up bowls, machine guards, oily waste cans, safety lanterns, industrial hospital supplies, protective hand creams, soaps, skin cleansers, athlete's foot preventives, floor scrubbing compounds and floor maintenance machines—just to mention a few. It was a splendid opportunity to get posted on the newest means for preventing accidents and promoting all phases of safe living, whether in public places, the home or factories. Judging from the crowds constantly swarming in the aisles, the display was highly appreciated.

LAST MEMBER OF LIBBEY FAMILY DIES IN TOLEDO

Sarah M. Libbey, sister and last surviving member of the family of Edward Drummond Libbey, glass pioneer, died in her home in Toledo on September 29. She had been ill for three years.

Miss Libbey, who died at the age of 90, had been a resident of Toledo since 1892.

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★ **BOTTLE STACKERS**
Efficiently handles bottles up to 2 quart capacity, automatically.

★ **BENDING FURNACES**
Straight line production units to bend glass components accurately to curvatures.

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For producer gas lines. Tight sand seal without metal to metal contact. 36 to 96 inch dias.

★ **HYDROSTATIC BREAK TYPE BOTTLE TESTERS**
Fast, accurate, safe. For various shapes and sizes of containers.

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Designed and built with all machinery installed in position.

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ACCEPTANCE SAMPLING . . .

(*Continued from page* 585)

consideration of the possibility of the effect of segregation within the lot should be given in planning the sampling procedure.

An attempt has been made in this paper to indicate some of the points which confused the writer in his earlier acquaintance with acceptance sampling, and to present his explanation and interpretation of these points. The discussions of Grant[1], Enwell[7] and others should prove to be helpful in a more detailed consideration of this subject of Acceptance Sampling.

REFERENCES

[1]E. L. Grant "Statistical Quality Control", McGraw-Hill, New York, 1943. Appendix III, Table G, pg. 542.
[2]E. C. Molina "Poisson's Exponential Binomial Limit" D. Van Nostrand Co., Inc., New York, 1942.
[3]Statistical Research Group, Columbia University "Sequential Analysis of Statistical Data: Applications." Columbia University Press, New York, 1945.
[4]H. F. Dodge and H. G. Romig, "Sampling Inspection Tables," John Wiley & Sons, Inc., New York, 1944.
[5]"Sampling Inspection", McGraw-Hill Book Co., Inc., New York, 1948.
[6]"Sampling Procedures and Tables for Inspection by Attributes", MIL-STD-105A, Supt. of Documents, Government Printing Office, Washington, 1950.
[7]"Quality-Control Handbook" J. N. Juran, Ed. McGraw-Hill Book Co., New York, 1951. J. W. Enwell "Statistical Methods in the Quality Function", Sect. 7, pg. 551, et seq.

PACIFIC COAST MEETING . . .

(*Continued from page* 588)

Glass Company factory rounded off the Glass Section's program, as it afforded an opportunity to inspect the tank and to gauge the efficiency of operation by the quality of the product.

In 1953 the Pacific Coast Regional Meeting will be in San Francisco, and in 1954 it will be in Los Angeles. The glass group on the West Coast extends an invitation to all associates throughout the industry to help make these meetings increasingly successful.

INTERNATIONAL MINERALS SELLS INNIS, SPEIDEN NAME

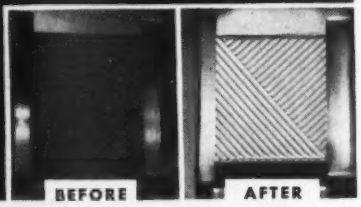
International Minerals & Chemical Corporation has sold the name of Innis, Speiden & Company, Inc., and its resale chemical business to Berkshire Chemicals, Inc., of New York, A. Norman Into, Vice President in charge of International's Potash Division, has announced.

In making the announcement, Mr. Into explained that when the firm bought Innis, Speiden in 1951, its major purpose was to acquire the electrolytic plant and facilities at Niagara Falls enabling International to follow its main objective of expanding vertically production of potassium chemicals. In that way, chemical products could be taken from International's mines and put into finished form for industrial consumers.

Although International has sold the other segments of the original Innis, Speiden business, it has retained the Niagara Falls facilities and plans to spend more than one million dollars for improvements which will increase production of chemicals and chlorine products by about 25 per cent.

• Appointment of Thomas C. Keeling, Jr., as Director of the Chemical Division of the National Production Authority, has been annuonced. Before his present appointment, Mr. Keeling served as Deputy Director of the Division.

Hydro-Finish leaves glass molds
READY for USE!

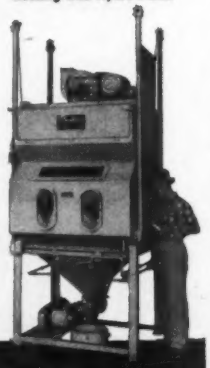


Actual unretouched photos of mold before and after cleaning with Hydro-Finish

Complicated molds are easily cleaned and left *ready for use* with Pangborn Hydro-Finish! Hand cleaning and polishing is virtually eliminated! And you save additional time and labor because a Hydro-Finish machine, operated by one man, removes discoloration and scale in *minutes* instead of hours!

What's more, Hydro-Finish's use of fine-mesh abrasives suspended in liquid gives you a precision job. Sharp edges are maintained . . . tolerances are held to .0001 . . . molds last longer . . . precision equipment is protected.

Get complete facts on Hydro-Finish and how it can save *you* money! Write for Bulletin 1400-A to: PANGBORN CORP., 3400 Pangborn Blvd., Hagerstown, Md.



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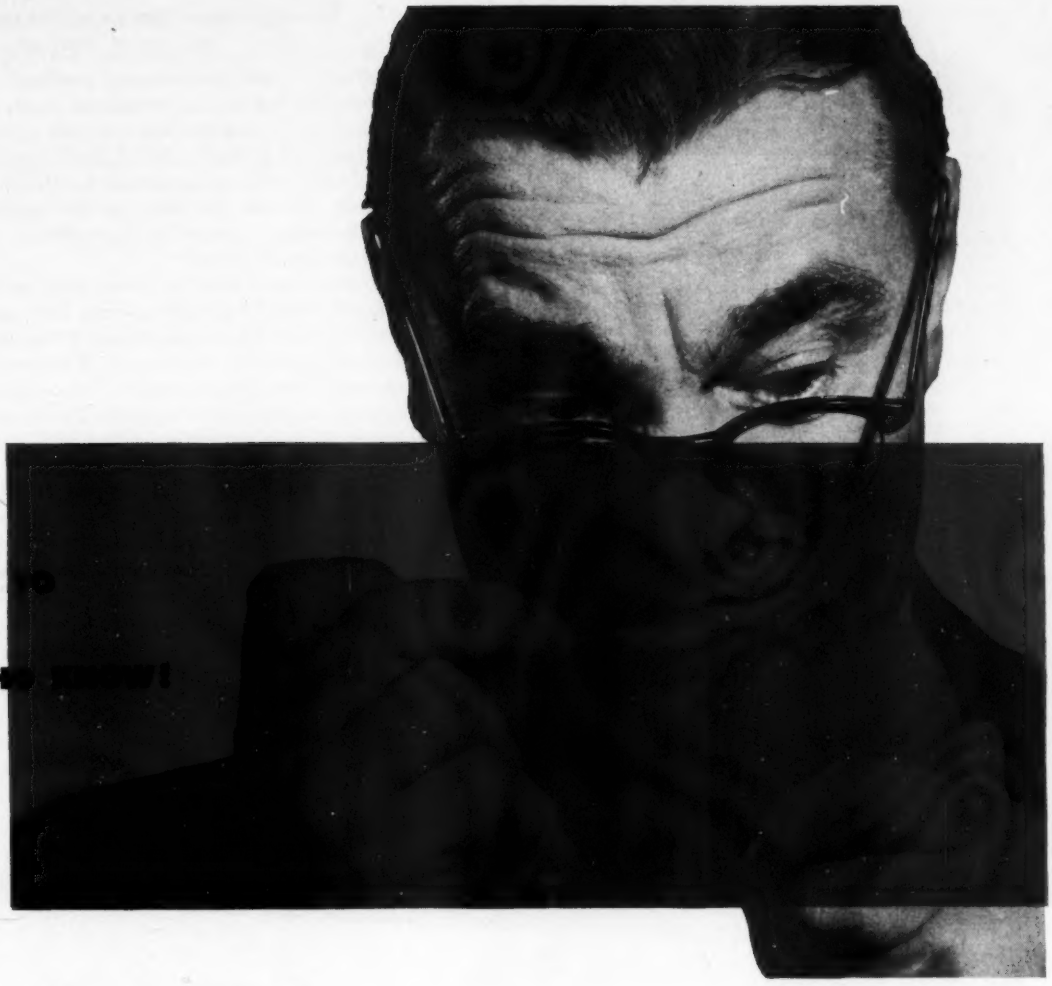

LEAVE IT TO

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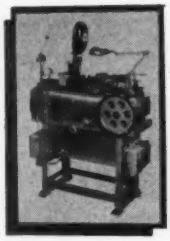

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GLASS FIBER INSULATED BLENDER

A new idea in home heating and a new kind of glass fiber insulation have been teamed together to enable easy, economical installation of modern heating—plus cooling, if desired—in old dwellings as well as in new homes.

The heating idea is Blend-Air, a high-velocity, forced warm air system manufactured by the Coleman Company, Wichita, Kansas, and the glass fiber material is Ultralite, an insulation product of Gustin-Bacon Mfg. Company, Kansas City, Missouri.

Because the glass fiber material is flexible enough to be slipped through a small opening into the stud space of walls of existing homes, heating modernization is simplified and costs and alteration mess are reduced. To install steel blenders, it is necessary to open the stud space to a minimum depth of 51 inches. By using Ultralite, only two small openings in the wall are required.

The flexible blender, with one header attached, is fed through the top opening until the free end reaches the lower opening which generally is at baseboard level. The second header then is attached to the glass fiber tube. Because the blender always returns to its original shape, it readily confirms to the stud space. The final step is adding the grilles, top and bottom. These cover the metal headers and conceal the rough edges of the wall openings.

• Dr. Alexander Silverman, Professor of Chemistry Emeritus in the University of Pittsburgh, will address the Early American Glass Club of Cincinnati at the Metropole Hotel, November 22. His subject, "Glass, Symbol of Infinite Variety," will be illustrated by experiments, specimens and colored lantern slides.

GLASS BOATS RACE FOR GLASS AWARDS

Glass boats raced for awards at the National Rebel Glass Championships held on the Maumee River late in September. Winner of the two-day event was the Rebel craft owned and skippered by William Berger of Jackson, Michigan, and a member of Clark's Lake, Michigan, Yacht Club. Eldred (Bud) Kennedy, also of Clark's Lake Club, was Mr. Berger's crewman on the victory run.

Mr. Berger received an engraved glass plaque, donated by Libbey-Owens-Ford Glass Company, and presented by G. W. Hibbert of the company's Public Relations Department.

Special gifts were awarded runners-up by Ben S. Wright, Vice President of Owens-Corning. Mr. Kennedy received a Fiberglas-insulated ice bucket for his role as crewman on the winning craft.

The Rebels are Fiberglas-reinforced plastic sailboats, 16 feet long and 6½ feet wide. Owners report that they require little maintenance because they do not rot or rust; are leakproof and worm proof; and do not need sanding or caulking. Because of their durability and strength, they are not easily injured. The Rebel hull weighs only 400 pounds.

• Professor S. M. Marco has been named Chairman of the Department of Mechanical Engineering at Ohio State University. He succeeds Professor Aubrey I. Brown, Chairman since 1946, who asked to be relieved of the chairmanship to devote his time to teaching.

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